S. Hrg. 98-1175

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1985

HEARINGS

BEFORE THE

SUBCOMMITTEE ON
ENERGY RESEARCH AND DEVELOPMENT

OF THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

SECOND SESSION

ON THE

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS

MARCH 5, 12, 20, 22, APRIL 5, AND 24, 1984

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DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1985

MONDAY, MARCH 5, 1984

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The subcommittee met, pursuant to notice, at 10 a.m., in room SD-366, Dirksen Office Building, Hon. Pete V. Domenici, presiding.

Present: Senator Domenici.

Also present: Paul Gilman, professional staff member; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator DOMENICI. The hearing will come to order. Let the record indicate we have inquired on the minority side and staff has informed us we should proceed. Distinguished Senator Ford is going to be unavailable this morning. If they have any questions, they will be submitted to you, Mr. Secretary.

We have before us the Assistant Secretary of the Department of Energy. His area is environment, safety, and health of that Department. These are oversight hearings to take a look at the budgets that have been submitted, and we are delighted to have you with us today.

This is the first opportunity we will have to review the 1985 budget for policy, safety, and environment. We've had you before the committee, but not in this capacity. You were Assistant Secretary for Fossil Energy. You appear before us today for the first time in this new capacity as head of the policy programs, which is the subject of the hearing. We have your prepared testimony. It will be made a part of the record, and we would like you to summarize it and take as much time as you would like in that regard. I understand you would like to amplify your prepared remarks with some other information you want to share with the subcommittee. You may proceed.

STATEMENT OF JAN W. MARES, ASSISTANT SECRETARY FOR POLICY, SAFETY, AND ENVIRONMENT, DEPARTMENT OF ENERGY

Mr. MARES. Thank you, Mr. Chairman. I am pleased to be here with you today to discuss with you the Department's budget request for fiscal year 1985 for the Office of Environment, Safety, and

Health. With me to assist in responding to your questions is Robert W. Davies, the Deputy Assistant Secretary for Environment, Safety, and Health.

I think it's quite clear that the Department is committed to the fact that we want our activities to be operated in a safe, healthy, and environmentally sound manner. Thus, the functions of the headquarters of the Environment, Safety, and Health organization are to establish departmental policy, provide guidance and technical assistance, oversee implementation of policy and guidelines, and perform an independent overview and assessment role for the Secretary.

As a consequence of that, as well as the activities of the line organization, the Department's safety and health record in 1983 was totally outstanding.

I would like you to turn to the charts which I believe you have in front of you which, if we can go through sequentially, would show you how the Department's record has been compared to its own performance as well as compared to outside indicators. I think as you leaf through and look first at the incidence of injuries in 1983, they are less than the average, both within the Department and externally.

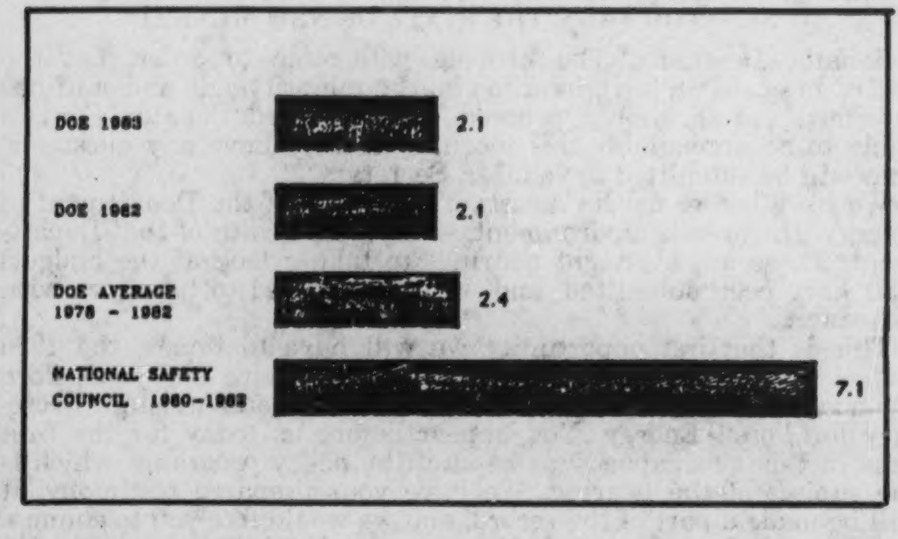


Figure 2. Recordable Injury/Illness Incidence Rate (Cases Per 200,000 Workhours)

The next chart is workday incidence rate which shows the severity of the accidents; again, less than Department records.

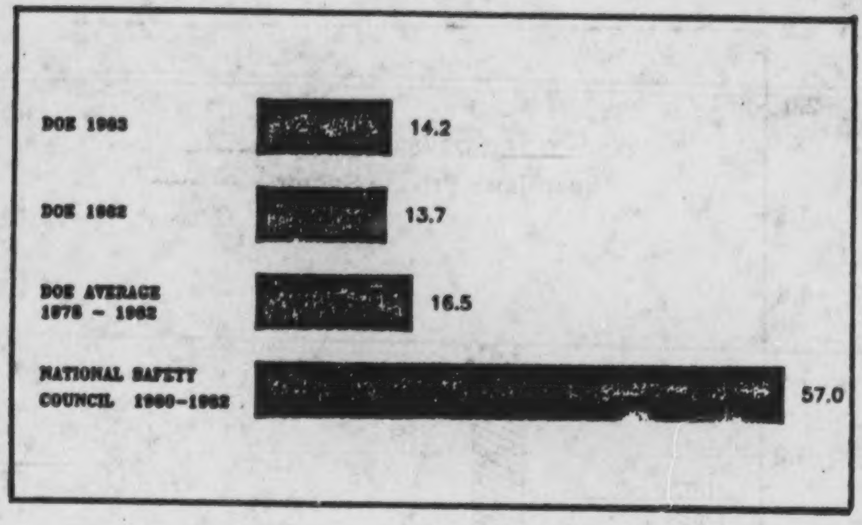
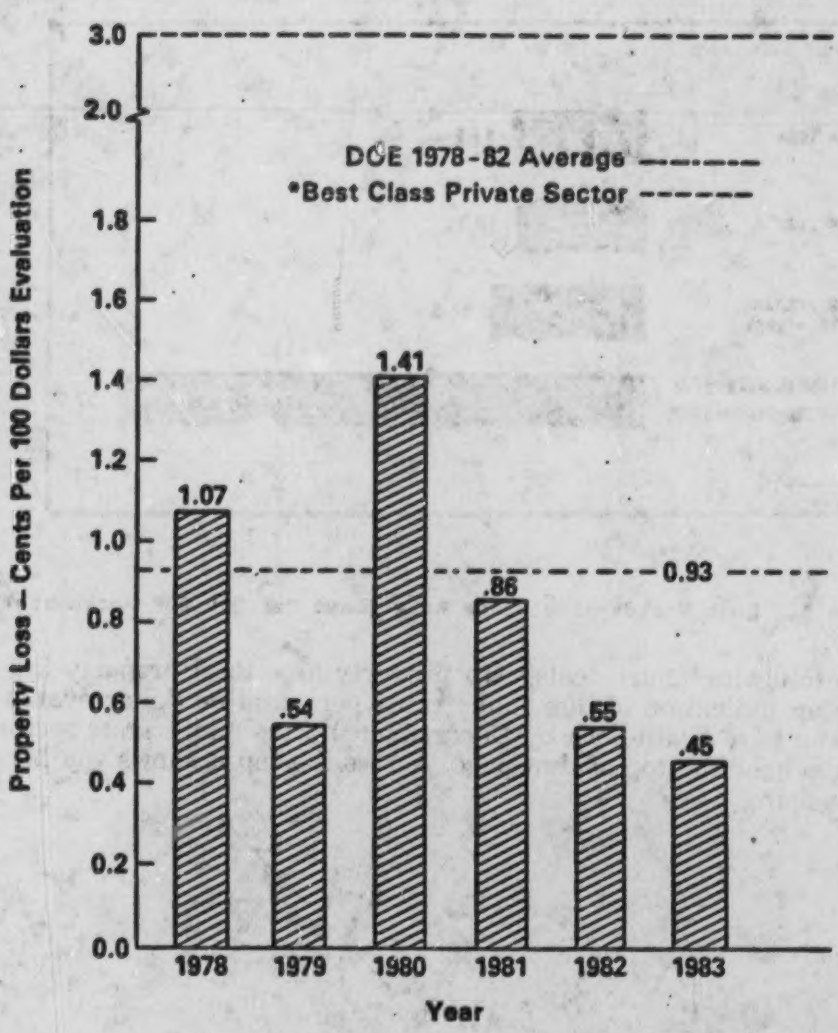


Figure 3. Lost Workday Incidence Rate (Days Per 200,000 Workhours)

The following chart deals with property loss, total property loss, and is an indication of how many cents per hundred dollar evaluation; and here again both by Department norms and private sector which is near the top of that page. Across the top it shows you how we are doing.

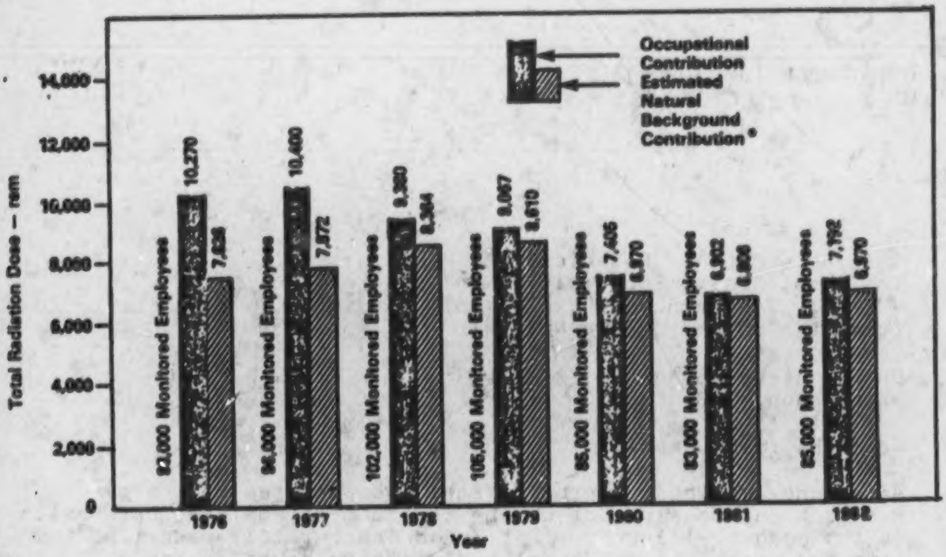


*From discussions with engineering personnel from the fire insurance groups.

Figure 3. DOE and Contractor Total Property Loss Rates

The next chart is headed radiation dose. There the solid dark line is the total radiation exposure that our employees receive, both from working at our facilities as well as natural background. The hashed line is what they received from background. So you can see that very little bit additive to the background is what, in fact, they are receiving from our facilities. By all standards, they are well under the norms that are expected.

RADIATION DOSE



* This assumes an average exposure level

Figure 11. Comparison of Total Radiation Dose Received by DOE Monitored Employees and Dose Received from Natural Causes

The next chart——

Senator Domenici. When you say background——

Mr. Mares. That's the natural background which is around 120 millirems.

Senator Domenici. Would it literally mean that the workers—Well, let's just take Los Alamos Scientific Lab, that there would be a certain natural dosage which is from the environment they live in?

Mr. Mares. Correct.

Senator Domenici. And that's shown on this graph as the hashed bar. They would be exposed to only the difference between the hashed and solid one?

Mr. Mares. Correct, as a result of their work experience.

[Mr. Mares submitted the following:]

Department of Energy
Washington, D.C. 20585

MAR 0 6 1984

Honorable Pete V. Domenici
Chairman, Senate Subcommittee on
Energy Research and Development
Committee on Energy and Natural
Resources
United States Senate
Washington, D.C. 20510

Dear Chairman Domenici:

After the hearing yesterday of the Subcommittee on Energy Research and Development on the Environment, Safety, and Health (ES&H) budget, I learned that I had inaccurately described the attached chart showing total radiation exposure to the Department of Energy (DOE) workforce. The captions are correct. The total exposure that the DOE personnel have received from DOE operations and the total exposure from natural background radiation is the amount of each bar for the year in question. The total exposure for the workforce from operations is a small fraction of the established limits for radiation exposure. Thus the point of this chart is that the exposure of the DOE workforce to radiation from their work experience is small, is declining, is about equal to that received from natural background, and by existing standards is not a health hazard.

I trust that this will clarify the explanation that I gave yesterday. I will suggest appropriate changes or footnotes in the record in order to clarify my statement.

Sincerely,

Jan W. Mares
Assistant Secretary for
Policy, Safety, and Health

Mr. Mares. The next chart indicates the percent of our monitored employees, and we monitored 80,000 employees who received more than one REM or two REM's. The significance is that five REM's is the standard by which NRC and the others judge as to what is the maximum allowable limit that employees should receive in the course of a year. This shows a very small percent of our people receive more than one REM, or more than two REM's; and, in fact, no employee received a dose in excess of the allowable five REM limit.

EMPLOYEE EXPOSURE DOSES
GREATER THAN 2.0 REM

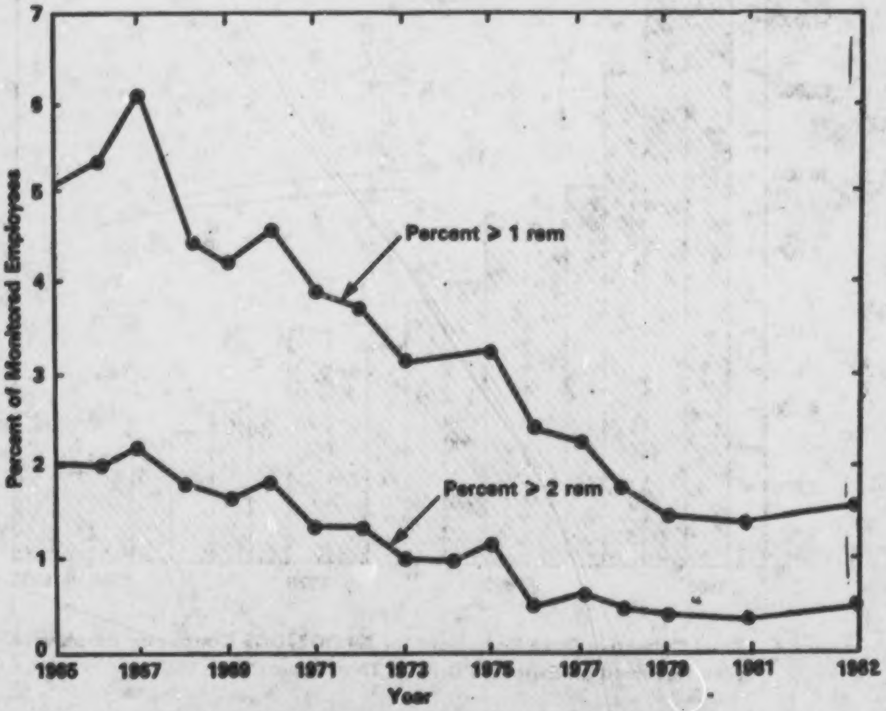


Figure 10. Percentage of Employees Receiving External Doses Greater than 1 Rem and Greater than 2 Rem (5 Rem per Year DOE Standard)

Senator Domenici. Where do your limiting standards come from in reference to this exposure?

Mr. Mares. Our standards are the same as the National Council on Radiation Protection and Measurements [NCRP], that is, five REM limit, as recommended by the EPA.

Senator Domenici. So this is not as in some areas where DOE does its own in measuring this against the standards set by some other entity that's in charge of this?

Mr. Mares. Correct.

Senator Domenici. Read this last graph for me. I can understand the one and two, but how do we know how many people? Where do we have the percent of people, or the number of people that are in each of these categories?

Mr. Mares. On the left side, it is the percent of total monitored population. The monitored population is about 80,000, and that would be the number of that population whose exposure was under that.

The final graph shows the total collective dose of those people who received more than one REM. What it's showing is that over time that collective dose is being reduced, and that's as a result of a very firm policy we have of trying to reduce radiation exposure to as low as reasonably possible, or reasonably attainable.

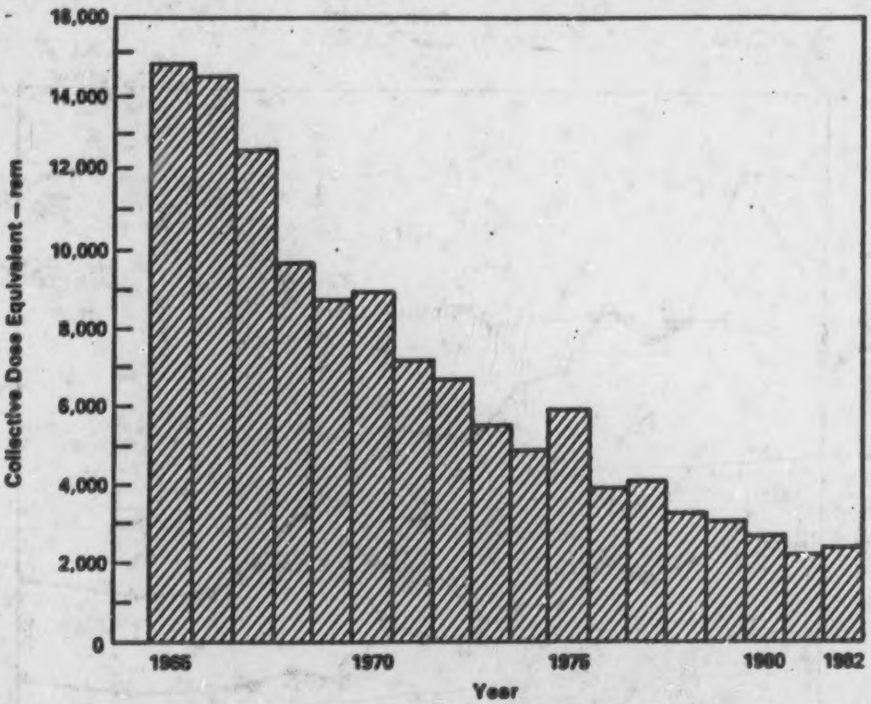


Figure 4. Total Collective Dose Equivalent for All DOE/DOE Contractor Employees Who Received an Exposure Greater Than 1 rem, 1965-1982

Senator Domenici. Why do we stop in 1982?

Mr. Mares. I didn't have the 1983 figures. I think the trend was generally continued.

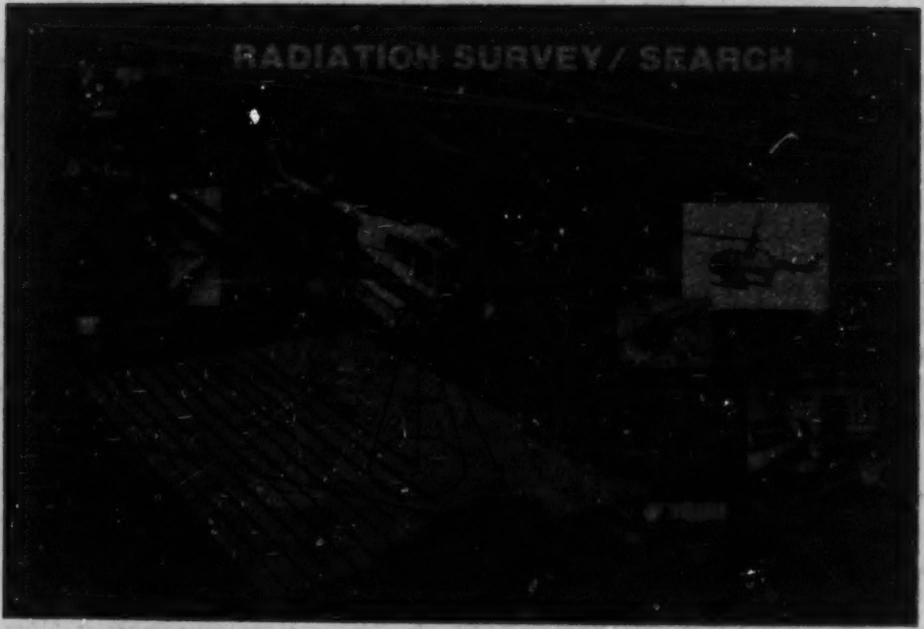
Senator Domenici. There won't be any 1983 aberration report on either chart?

Mr. Mares. There might be a statistical one, but there's no gross change.

In fiscal year 1985 we are requesting $37 million for our Environment, Safety and Health Program, and that's $5 million more than was appropriated in fiscal year 1984. The increase is primarily in the nuclear safety area even though the Department's nuclear safety record, I think, is clearly outstanding. This planned increase is considered necessary for us to assure continued safety of operations as well as to improve upon our excellent safety record. It is primarily in health physics for improving and standardizing plant measurement and operating procedures and in emergency response by enhancing the remote sensing capabilities of the aerial measurement system [AMS]. It is also in the criticality safety areas.

These charts that you have in front of you relate to the remote sensing AMS. This day in El Paso, TX and Juarez, Mexico our organization is working with the State authorities in both locations to perform aerial measurements of radiation from small particles of cobalt 60 which came from a cancer treatment machine which was put in a storage yard and then broken up, put into a scrap yard and then used in a foundry. That radioactive material in these particles in the foundry were converted into rebar and table bases. When a load of rebar left Los Alamos, the radiation detectors went off and caused us to become aware of it. We tracked it down to this particular foundry in Juarez, Mexico. So our people are down there using these very sophisticated techniques which are available to State and local authorities, as well as our own facilities. We need it. What they are trying to do is find out where the various particles, that are about the size of a grain of sand, are to the extent that they have not been encompassed within the materials that have already been distributed. There is no judgment that there is any harm to the public health of anyone in the United States, but it is desirable to be sure that none of these particles came across the border, or are found along the highways or anywhere in the El Paso, TX area, or the immediate environs of New Mexico.

What these three charts, in simple terms, show, the first chart shows how we set up two locational devices that can radio information to the helicopter, or fixed wing aircraft as the case may be, to allow it to know precisely where it is over land surface. It also has instruments to detect the radiation, the level of radiation, the amount of it, the type of it. That information is then assimilated in a data analysis program which allows us to come up with charts which show where on the land surface there are hot spots, and then we can go with ground carried instruments to those places and find the individual radioactive particles. They can then be collected in a proper and safe way and the potential hazard eliminated. The last time we deployed this force in any significant way was when the satellite came down a couple of years ago, and we were ready to do it a year ago when the satellite almost came down as well.


RADIATION SURVEY / SEARCH

AIR CARGO
POD SYSTEMS
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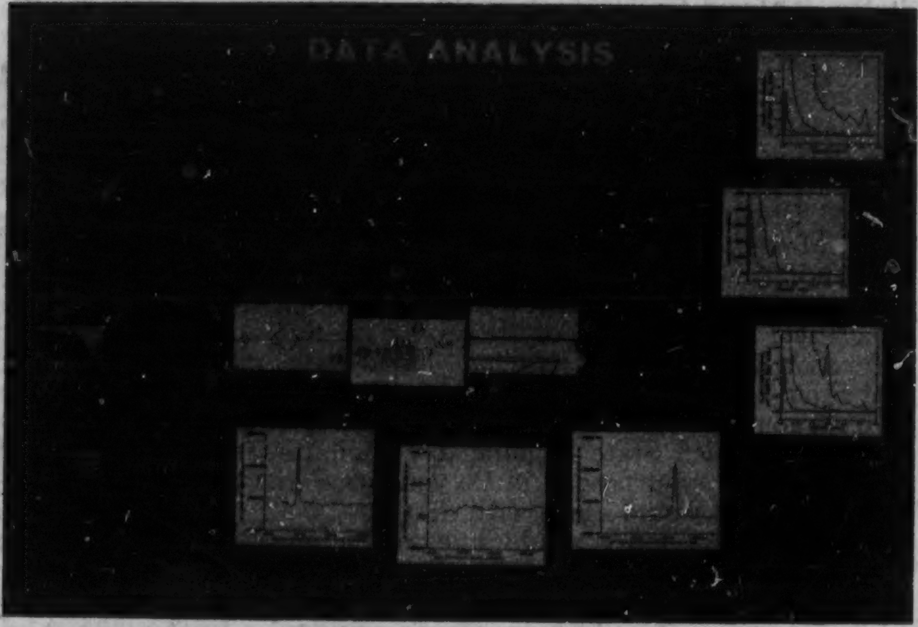
PHOTO
COMMUNICATIONS



DATA ANALYSIS

Senator DOMENICI. Let me ask you about this one for a minute. First, I appreciate your bringing to the committee the information regarding this approach by the Federal Government in this capacity that we have. But in looking at it before this hearing I had a sense that the events as I saw them develop pointed up somewhat of a deficiency in the Federal-State relationship in this area and our ability to respond to these events as between the States and the Federal Government.

Let me see if I can ask you a couple of questions about that. The original discovery that the steel was contaminated was made in Los Alamos as I understand it by radiation monitor there; s that correct?

Mr. MARES. That's correct.

Senator DOMENICI. And then Texas and New Mexico, when informed of it, sought help from the Federal Government providing additional monitors at the border; and as far as this aerial survey of the border, they sought help from the Federal Government to see if further radiation risks were involved. They thought that these tiny pellets of cobalt 60 that are the source of the contamination might come across the border in tires of automobiles or trucks as I remember.

Mr. MARES. That's correct.

Senator DOMENICI. Now I understand when the Federal Government was asked to participate as far as this aerial survey, it took about a week to respond?

Mr. MARES. That would not be my understanding.

Senator DOMENICI. I hope it's not so. Can we find out?

Mr. MARES. I asked at the time we first became aware of it, and we had already, at that instant, volunteered the service. We basically have the only comparable service like this in the United

States. It's paid for by the taxpayers. They are entitled to get the benefit of it. We try to make it available whenever there is such an event. So I'm disheartened that your information would indicate we had not been forthcoming.

Senator **Domenici**. I also understand now that some of that delay was that someone in the Department was trying to find out what the State's responsibility to reimburse, that is Texas and/or New Mexico. Did anybody ever say that to either of the States?

Mr. **Mares**. I don't know whether they did or didn't, but my understanding is we have tried to make this service available where it's needed and worry about those other things afterward. I mean the critical thing is to make the service available.

Senator **Domenici**. If it is what you say it is, it seems to me that that should be the case. I don't know why we have this available as an emergency diagnostic tool if we are going to sit around and try to find out which State is going to contribute. I would think that would defeat the purpose of it. Do you agree with that?

Mr. **Mares**. I would agree with that.

Senator **Domenici**. I would like you to make sure that didn't happen and get us something for the record. We have an indication it was ongoing dialog between the State of Texas and your Department as to where reimbursement was going to come from. That attributed to some delay. I'm telling you what I've been told. That's the only way I can find out. Your people didn't tell me that.

Tell me now what will happen as we conclude this?

[The information follows:]

I have looked into the events leading up to our survey operation in El Paso. At every step we have had nothing but the best of relations with both New Mexico and Texas officials.

We first became aware of the contamination problem on January 17, 1984, when a load of rebar triggered our radiation portal monitors at Los Alamos. Thereafter, we tracked the problem for several weeks from the viewpoint of watching where the rebar and other manufactured goods were discovered in the U.S. Many of our field offices provided assistance to various states during this period. This assistance ranged from offering advice to loaning equipment, as was done for New Mexico. On February 2, 1984, we were informed by the U.S. State Department staff that there was considerable contamination in Mexico, not only from the manufactured products, but more seriously from the small pellets which had been scattered before the cobalt-60 entered the scrap cycle. The State Department wanted to know if we could conduct an aerial survey of the Juarez, Mexico, area, assuming proper clearances were obtained. We told the State Department we could do the survey, but would need a formal request from Mexico. We immediately informed our survey operation, the Aerial Measuring System, that such a survey was a possibility, but no deployment was authorized until appropriate Mexican authorities agreed with the need for our survey services.

We continued to maintain contact with the staffs of both the State Department and the NRC International Programs Division on a possible aerial survey in Mexico. However, late on February 14, 1984, we received a call from the NRC Office of Inspection and Enforcement indicating that the State of Texas wanted an aerial survey of the El Paso area. They said Texas felt this survey was required to determine if any of the pellets had been tracked over the border. At 5:50 p.m., on February 14, 1984, we contacted the Chief, Bureau of Radiation Control, Texas Department of Health, to confirm their request and to begin making arrangements for the survey. At that time, we were invited to a meeting in El Paso on February 17, 1984, to which we sent representatives from our Nevada office, the operational managers of the Aerial Measuring System. Besides the Department's and Texas' attendees, New Mexico; El Paso; NRC; U.S Customs; and several Mexican organizations were represented at that meeting. While DOE was asked a general question on survey costs at the meeting, our representatives did not discuss with either New Mexico or Texas reimbursement for survey costs. We have continued to make it clear that our response was based on need only.

After this preliminary meeting, we began preparations to deploy a survey team, including one of our helicopters with its sensitive detection equipment. We received the formal requests for surveys from Texas on February 22, 1984, and from New Mexico on February 23, 1984, and authorized our team's deployment on February 24, 1984. We conducted an aerial photography mission on February 27, 1984, while all of our equipment and personnel were enroute to El Paso. On February 29, 1984, our team met with all concerned and the survey began on March 1, 1984. The U.S. portion of the aerial survey, which included a small area of New Mexico, was completed on March 13, 1984. There was no indication that any of the cobalt-60 pellets are in the El Paso area. I am confident that the sensitive instruments we used there would have found the pellets, had any been there.

As an adjunct to this aerial survey, next week we will be responding to the request of the New Mexico Radiation Protection Bureau to see if any pellets are along two highway routes between Santa Fe, New Mexico, and El Paso, Texas. This will be done by driving sensitive detection equipment mounted in the Department's health physics van from Los Alamos National Laboratory along the requested routes and giving the results to the New Mexico authorities.

As requested by the Subcommittee staff, we will provide copies of letters from the States of Texas and New Mexico reflecting the Department's responsiveness to the states' requests, when they are received.

Mr. MARES. The information will be made available to the local public health authorities, and then we will know exactly where the ground contamination is to the extent that it is on the surface there in the El Paso or New Mexico area; and, in fact, we even, through the State Department, offered to provide this service to the Mexican authorities for the same purposes. We would expect that we will be doing this survey for about 10 days in the El Paso area, about 4 in the Juarez area. In terms of specifically who does what regarding the identified contamination on the ground, I don't have that information. We are prepared to provide it to you. I mean I just don't know the answer. I am sure people on the staff could. The people who are in charge of that are in a different event that I'm going to talk about in a minute dealing with energy emergency preparedness.

Senator DOMENICI. What about FEMA? Are they involved?

Mr. MARES. To my knowledge they are not.

Senator DOMENICI. From what you are saying, this will be available. The 10 days that you have established is what you think it will take to get the answers?

Mr. MARES. That's correct.

Senator DOMENICI. That's not an arbitrary time. That's what you figure it's going to take for this kind of equipment to get the data down, and then it's somebody else's job?

Mr. **Mares**. Obviously, but to the extent there is a technical need, we are going to provide, to the extent that we've got the competency in the area.

One of the programs that we have underway in 1984 that I wanted to mention is the testing of the Federal radiological monitoring and assessment plan actually starting today and continuing for the next 3 days at the St. Lucie nuclear power plant in Florida. There will be a combined Federal, State, and local as well as public utility, field and headquarters level, exercise of the emergency capabilities that we as a Nation have collected to deal with potential accidents.

Next week I could report to you on what happened because I'll be going down there tomorrow night to observe that testing process. One of our people, in fact, quite a few of the Department's people, about 100 in total, are involved in this, including this capability. It is available in the event of an accident to quickly determine what is the extent and scope of radiation from that accident.

At this test, we have two helicopters and one fixed wing aircraft that are involved in that, people from all of our operation offices, as well as from several of our contractors.

I've just identified really only one of the things in some detail that we have worked with in our office here, but I think the combination of that, of those sorts of activities, our policies and independent overview, have helped the Department to continue its excellent record of safety, health, and environmental compliance at the departmental facilities. I think this program to date has assured the national energy policies and departmental plans, programs and operations have effectively addressed and expeditiously resolved environmental and safety problems. We think the proposed fiscal year 1985 budget provides the resources necessary to continue a strong independent environment, safety and health overview of the departmental operations and activities, and to enhance our efforts in some areas.

I would be prepared to answer any questions that you may have either now or subsequent.

[The prepared statement of Mr. Mares follows:]

Statement of Jan W. Mares
Assistant Secretary for Policy, Safety, and Environment
Department of Energy
FY 1985 Appropriations Hearings

Mr. Chairman and members of the Subcommittee, I am pleased to be here today to discuss with you the Department's budget request for FY 1985 for the Office of Environment, Safety and Health. With me to assist in responding to your questions is Robert W. Davies, the Deputy Assistant Secretary for Environment, Safety and Health.

NATIONAL ENERGY POLICY PLAN AND SAFE, ENVIRONMENTALLY SOUND OPERATION OF DOE ACTIVITIES

The overall goal of our national energy policy is to foster an adequate supply of energy at reasonable costs. The two strategies to achieve this goal are (1) to promote a balanced and mixed energy resource system and (2) to minimize federal control and involvement in energy markets while maintaining public health and safety and environmental quality. The Department of Energy implements these strategies through many programs involving diverse activities from research and development like magnetic fusion to process services like uranium enrichment. In addition, the Department is responsible for the manufacturing of nuclear weapons for national defense purposes. The DOE Organization Act establishes the Departmental goal of protecting and enhancing environmental quality and assuring public health and safety.

Differently stated, the Department's goal is for all of its activities to be operated in a safe, healthy and environmentally sound manner.

The Department's health and safety record has been outstanding by any standard. Its environmental record has also been good and there are no substantiated cases of impact on public health from the Department's operations, even though there have been occasional allegations to the contrary. The Department has always been a leader in environmental protection through its research activities to define and avoid adverse environmental impacts from its operations. The Department has also made continuing efforts to be in compliance with applicable environmental requirements as they have changed through the years. In fact, planning is currently underway to modify certain previously acceptable practices to meet current standards.

The Headquarters Environment, Safety, and Health (ES&H) functions are to establish departmental policy, provide guidance and technical assistance, oversee implementation of policy and guidelines, and perform an independent overview and assessment role for the Secretary. The line organizations starting with the DOE contractor, continuing through the DOE operations office and the program office, have responsibility and accountability for the safe, healthy and environmentally sound performance of their activities.

Thus the ES&H Office has overall responsibility for establishment and oversight of policy implementation by line organizations to assure safety and health of the workers and the public, and protection of the environment at DOE's operations.

GOAL OF OFFICE OF ENVIRONMENT SAFETY AND HEALTH

The goal of the Office of Environment, Safety and Health is to assure safe and environmentally sound operation of DOE activities. This is done by providing the Secretary and the Department a competent, adequate, independent oversight capability at headquarters which (i) as appropriate reviews, assesses, appraises and in some cases approves, Departmental (including contractor) activities; (ii) develops appropriate policies, standards and guidance for DOE; (iii) identifies and supports research to assist DOE to operate in a safe and environmentally sound manner; and (iv) provides related technical (including quality assurance) assistance to Departmental activities to assist them in operating in this manner. These functions are performed while recognizing the unalterable responsibility of the line organizations for safe and environmentally sound operation of the activities under their supervision.

The recent realignment of functional responsibilities within the Department placed the Office of Environment, Safety and Health under the Assistant Secretary for Policy, Safety, and Environment. This change eliminated the previous split in management focus whereby the Assistant Secretary was responsible for both safety and environmental oversight as well as for several major outlay programs which required substantial management attention. The change will result in increased management attention to the Department's environmental programs and its nuclear and operational safety functions. This in turn is expected to bring about an increased emphasis Department-wide on the safe, and environmentally sound operation of DOE activities.

The Environment, Safety and Health Office provides to the Secretary and other senior managers of the DOE an independent overview assessment of, and technical assistance to the Department's management of its facilities to assure safe and healthful workplace conditions, the safety and health of the public, protection of the environment, and compliance with applicable ES&H-related statutory and regulatory requirements. The office also assures that energy issues compatible with national energy goals are considered in the development of proposed environmental requirements.

Achieving the Department's environmental, safety and health protection and quality assurance objectives hinges on a solid partnership between the Environment, Safety, and Health Office and the Department's line programs. The ES&H Office furnishes the line programs with applicable ES&H requirements through general policy orders, monitors their efforts in complying with these requirements, and assists with technical advice in resolving implementation problems. This allows the line organizations, which have the principal responsibility for safe and environmentally sound operations, to proceed with greater assurance that they will not incur interruptions from accidents or litigation stemming from non-compliance with ES&H-related laws or practices.

OUTSTANDING SAFETY AND HEALTH RECORD

The Department's safety and health record in 1983 was outstanding. The Department has the safety and health responsibility for 157,000 Federal and contractor employees who operate facilities with a property replacement value of about $65 billion. The Department's fatality, injury, and illness rates for FY 1983 were not only well below the rates of the private sector, (i.e., only 1/5th of the private sector's fatality rates and better than 1/3rd of the private sector's recorded illnesses and injuries rates), but also below the Department's own averages of its annual rates for the period 1978 through 1982. None of the FY 1983 injuries or illnesses were caused by radiation exposure, and there were no accidental exposures in excess of the various allowable annual limits. The total reported property loss for the Department in FY 1983 was approximately $3.1 million. The loss rate was approximately half a cent for every hundred dollars of property valuation which is a significant improvement over the latest 5-year annual average for DOE of .89 cent per hundred dollar valuation.

The accidents per million miles and dollar loss per 1,000 vehicle miles rates were less than one-half the comparable rates for all nation-wide travel, as reported by the National Safety Council. The Department also owns or contracts for 48 aircraft, none of which were involved in an accident. In addition, there were no marine or railroad losses reported during FY 1983.

Of the 85,000 employees routinely monitored for radiation exposure, only 43% received a measurable dose in 1982, the latest calendar year for which complete information is available. Of these, only 1.6% received a dose greater than 1 rem and no employee received a dose in excess of the allowable 5 rem limit.

The safety and health record indicates that the Department's performance in all areas continues to be far better than comparable rates for the private sector.

PRINCIPAL STATUTORY AUTHORITY

The statutory authority governing the ES&H Program includes the DOE Organization Act which establishes a Departmental goal of protecting and enhancing environmental quality and assuring public health and safety; the Atomic Energy Act which exempts DOE and its contractors from certain licensing requirements (The DOE requires that the Department's operations be conducted in accordance with comparable health and safety practices.); and the National Environmental Policy Act. This Act requires consideration of environmental factors in agency decisionmaking, including as appropriate, the preparation of environmental assessments and environmental impact statements.

PROGRAM ORGANIZATION

The Program's functions are carried out by five major components: Nuclear Safety, Quality Assurance and Standards, Operational Safety, Environmental Compliance, and Environmental Analysis. Their activities include the development of policies and standards; oversight to monitor program and field office performance in complying with DOE policies and standards, technical and policy guidance assistance to foster compliance; the review of National Environmental Policy Act documents; and the analysis of energy/environmental issues.

FUNDING

In FY 1985 we are requesting $37.1 million for the Environment, Safety and Health Program which is $5.0 million more than appropriated in FY 1984 as noted in the following table, and discussed in the following sections. The increase is primarily in the nuclear safety area even though the Department's nuclear safety record has been outstanding. The planned increase is considered necessary by the Department to assure the continued safety of operations and to improve on the Department's excellent safety record. It is primarily in health physics for improving and standardizing plant measurement and operating procedures, in emergency response by enhancing the remote sensing capabilities of the Aerial Measurement System, and in criticality safety by upgrading the safety assessments and the safety training for affected contractor and DOE employees. The remaining activities will continue at essentially the same level of effort as in 1984.

Funding Summary

(Budget Authority in Millions)

Environment Safety and Health	FY 1984 Appropriation	FY 1985 Request
Operating Expense:		
Nuclear Safety	$ 11.5	$ 16.2
Quality Assurance and Standards	0.9	1.0
Operational Safety	8.8	9.2
Environmental Compliance	1.5	1.7
Environmental Analysis	2.4	2.6
Program Direction	5.4	4.9
Subtotal	30.5	35.6
Capital Equipment	1.6	1.5
Total ES&H	$ 32.1	$ 37.1
Staffing - Full-time equivalent	95a/	95a/

a/ Excludes 2 FTE's budgeted under the Nuclear Waste Act Fund.

FY 1984 PROGRAM PLANS

The FY 1984 plans include:

- Conducting comprehensive environmental protection, safety, and health protection appraisals of three field organizations and of two Headquarters program offices. A comprehensive appraisal is comprised of in-depth appraisals of up to 10 functional ES&H areas performed in conjunction with, and as input to, a management appraisal of the organization being appraised.

  This comprehensive appraisal effort has resulted and is expected to continue to result in numerous ES&H improvements such as: enhancing the quality of field office reviews of nuclear facilities and upgrading overall contractor surveillance, through design reviews, construction monitoring, etc.

- Providing training to DOE and DOE contractor personnel in the areas of Human Factors, Nuclear Criticality Safety, Quality Assurance Awareness, and Prevention of Significant Nuclear Events.

- Expanding the criticality safety activities including the upgrading of the statistical measurements technical manual, used throughout DOE operational functions to insure control of fissionable material liquids, to include the latest up-to-date data.

- Testing the Federal Radiological Monitoring and Assessment Plan in an interagency field and headquarters level exercise with NRC, FEMA, state and local authorities and The Florida Power and Light Company personnel at the St. Lucie Nuclear Power Plant on March 6-8, 1984.

- Continuing field testing of prototype improved neutron measurement devices for workplace application.

- Conducting quality assurance surveys of Bonneville and Western Area Power Administrations to determine the status of policy implementation, thereby completing the initial base-line surveys at all major DOE sites, and performing in-depth quality assurance appraisals of four selected major projects (namely the Fuel Materials Examination Facility at Richland, the Assembly Facility at PANTEX, the Uranium Enrichment program at Oak Ridge, and the Crystaline Rock radioactive waste project under Chicago Operations Office) to determine adequacy of their quality assurance programs and activities to meet their needs and objectives.

- Issuing guidance to Headquarters, field, and contractor organizations for the conduct of environmental protection appraisals and audits incorporating industry practices.

- Implementing revised environmental assurance procedures for the DOE Remedial Action Program.

- Conducting fire protection surveys of five DOE sites (namely Brookhaven Laboratory, Bendix Plant at Kansas City, Mound Laboratory, Sandia in Albuquerque, and Argonne-West in Idaho) and issue initial guidelines for optimum fire management systems for fire environments specific to DOE.

- Completing action on about 600 requests from DOE programs for NEPA-related support, including: about 200 analyses to determine/confirm the level of NEPA documentation required for DOE actions, i.e., Environmental Impact Statement (EIS), Environmental Assessment (EA), or neither; and about 120 independent reviews of EIS's and EA's.

  Major EIS' include those for: the restart of N-Reactor; the Process Facility Modification at Hanford; the Special Isotope Separation Project; the Fuel Processing Restoration Project at Idaho; Bonneville Power Administration's Expanded Regionwide Weatherization Program; the Niagara Falls Storage Site Remedial Action Project; the Salt Lake City Remedial Action Project; and the Manitoba, Dakota, Nebraska (Mandan) 500 KV transmission line from Manitoba thru the Dakotas to Nebraska.

- Continuing to participate in Departmental assessments concerning acid rain and other transboundary air pollutants. Much of this work will be in interagency or international forums.

FY 1985 OBJECTIVES

In FY 1985 the Program plans to expand the overview and assessment efforts of Departmental activities to assure that environment, safety and health policies are effectively implemented. The principal objectives in FY 1985 include:

- Developing better training guidance for reactor and nuclear facility operators to improve operational safety at DOE nuclear facilities.
- Maintaining and improving the radiological emergency response capability for DOE facilities.
- Developing improved methods for measuring and assessing the amounts of inhaled or ingested radioactive materials to assure compliance with radiation exposure limits recommended by national and international authorities.
- Developing and implementing improved methodologies, particularly in the area of criticality safety, for assessing the safety of nuclear operations.
- Issuing revised environmental protection, safety and health protection guidance and conducting appraisals of ES&H performance at three Operations Offices.
- Issuing improved quality assurance and unusual occurrence reporting guidance based on the analysis of the initial base-

line survey completed in FY 1984; and appraising implementation of the guidance at six field or program offices.

- o Assisting DOE organizational units in preparing sound NEPA documents and performing reviews of all such required documents to facilitate Departmental programs.
- o Analyzing proposed regulations and statutes, such as modifications to the Clean Air and Clean Water Acts, to ascertain the potential impact on DOE program or interests.

SUMMARY

The ES&H policies and independent overview have helped the Department to continue its excellent record of safety, health protection, and environmental compliance at the Departmental operational facilities.

The Environment, Safety and Health Program to date has assured that national energy policies and departmental plans, programs and operations have effectively addressed and expeditiously resolved environmental and safety problems. The proposed FY 1985 budget request provides the resources necessary to continue a strong independent Environment, Safety and Health overview of Departmental operations and activities.

I am prepared to answer your questions or comments on this program.

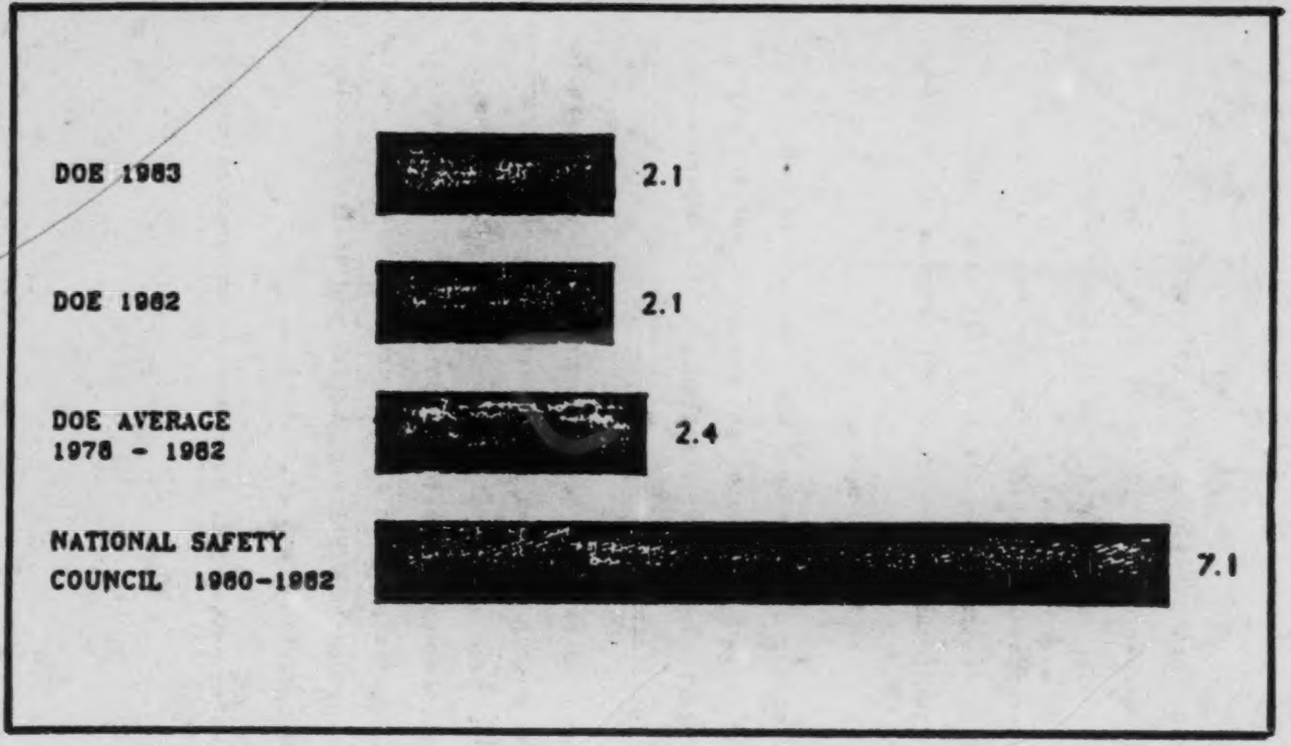


Figure 2. Recordable Injury/Illness Incidence Rate (Cases Per 200,000 Workhours)

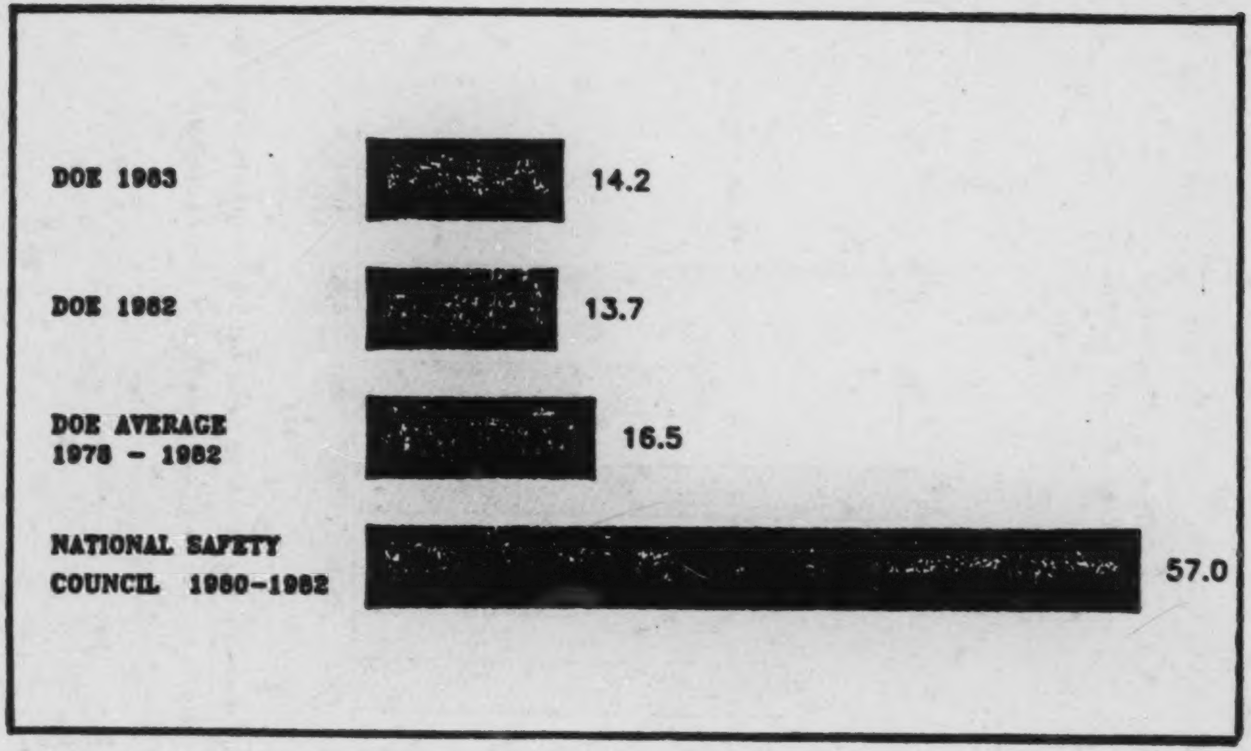
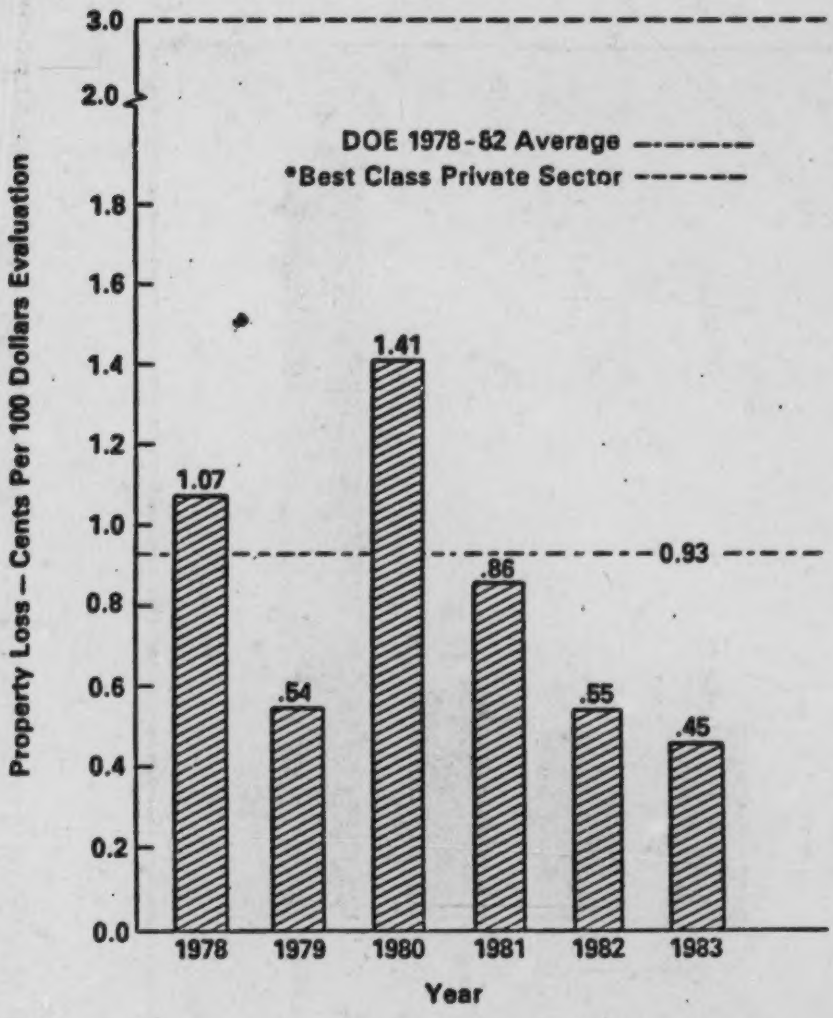


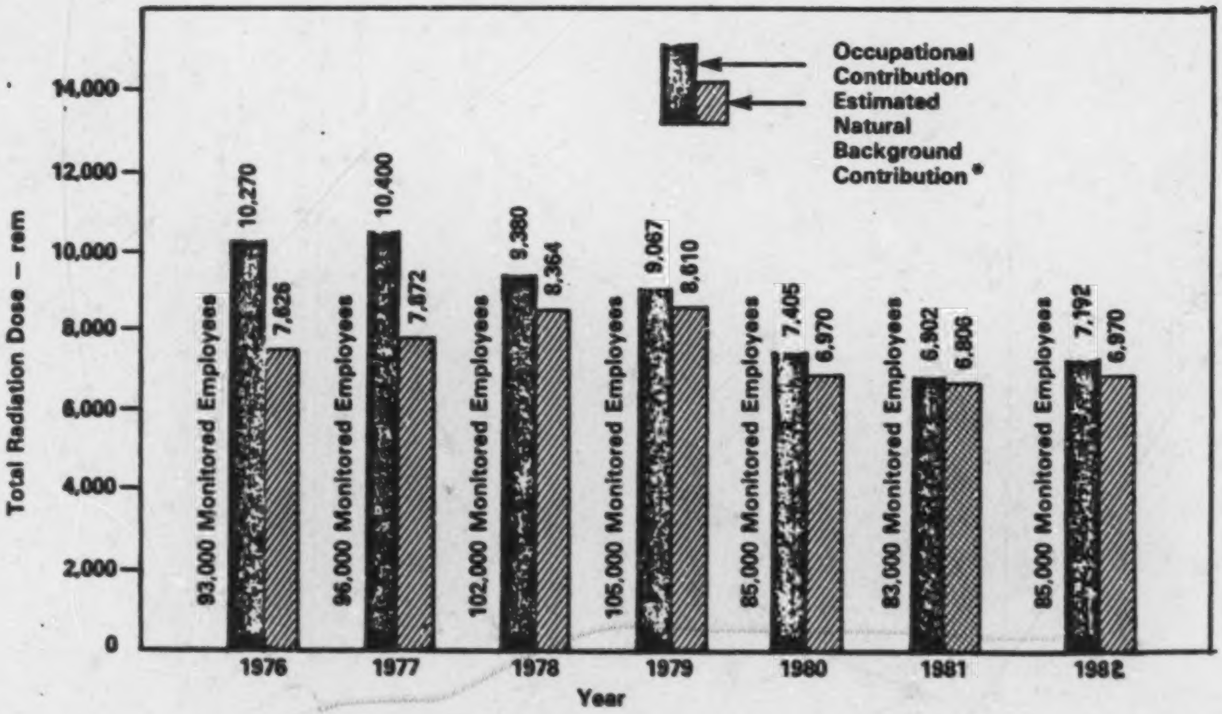
Figure 3. Lost Workday Incidence Rate (Days Per 200,000 Workhours)



*From discussions with engineering personnel from the fire insurance groups.

Figure 3. DOE and Contractor Total Property Loss Rates

RADIATION DOSE



* This assumes an average exposure level

Figure 11. Comparison of Total Radiation Dose Received by DOE Monitored Employees and Dose Received from Natural Causes

EMPLOYEE EXPOSURE DOSES GREATER THAN 2.0 REM

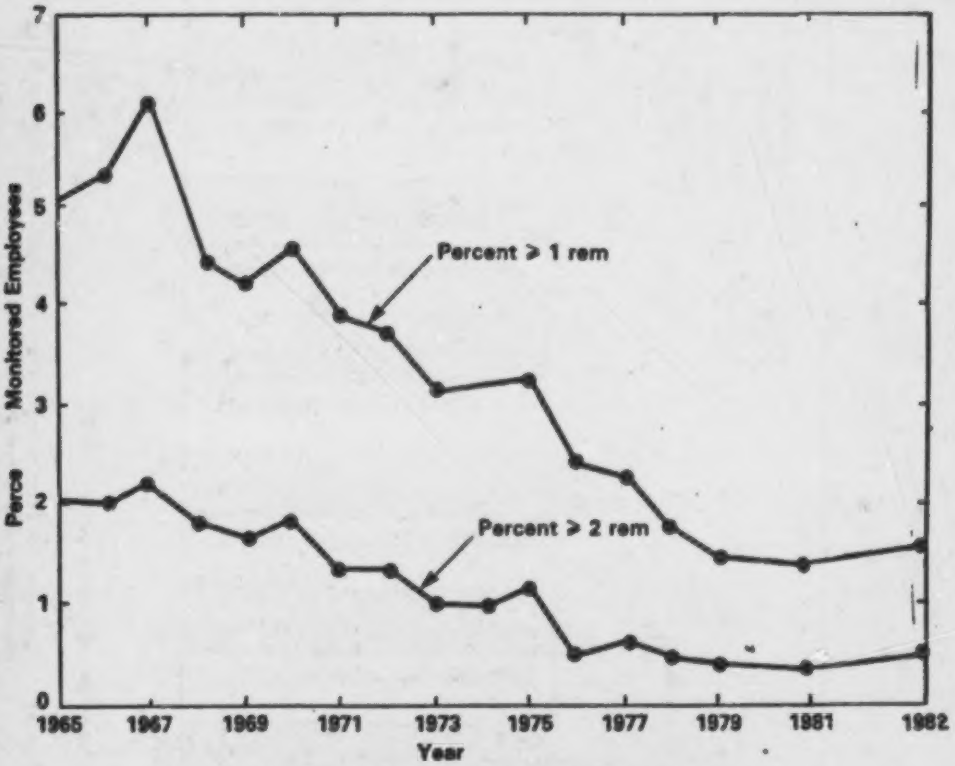


Figure 10. Percentage of Employees Receiving External Doses Greater than 1 Rem and Greater than 2 Rem (5 Rem per Year DOE Standard)

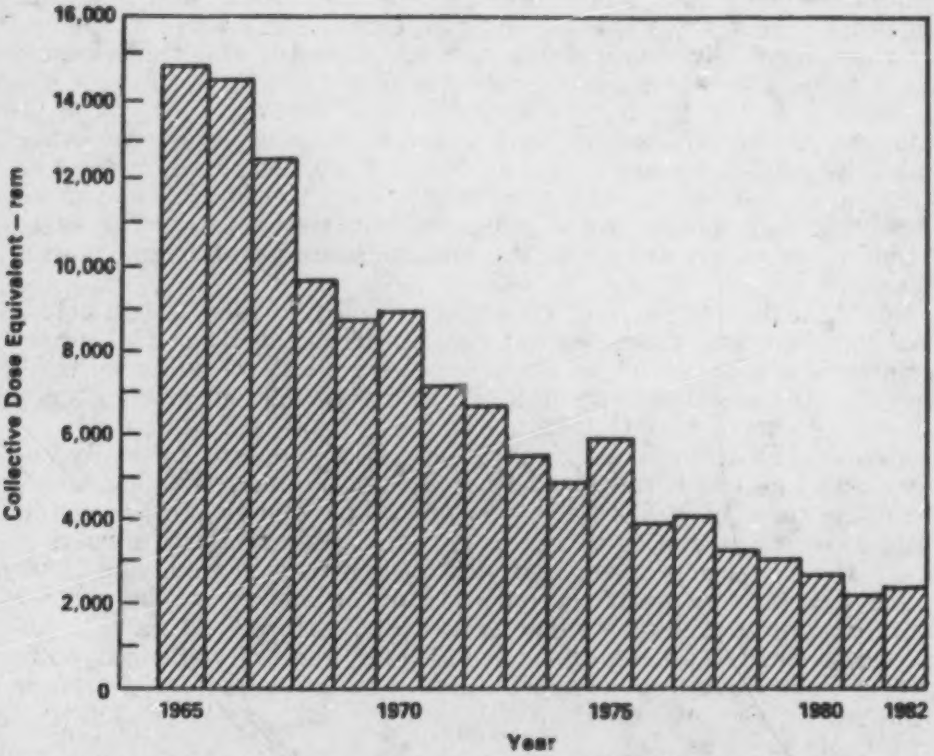


Figure 4. Total Collective Dose Equivalent for All DOE/DOE Contractor Employees Who Received an Exposure Greater Than 1 rem, 1965 - 1982

Senator DOMENICI. We have some that may be submitted in writing for you to answer. Let me move over to an area that is of some concern to us in New Mexico because of the existence of the Federal installations.

As we understand it, the Environmental Protection Agency is in the process of promulgating standards for the release of the airborne radionuclides. These standards would apply to the DOE facilities as well as civilian facilities. It's my understanding, and I've talked to my staff about this, that a number of professional groups have expressed some concern about the regulations. Could you comment on the nature of the Department's concern about the EPA regulations? It's my recollection—I am on the committee that wrote the base bill, but we didn't have any hearings, so there's not a lot of history on that. That was an amendment adopted on the floor as I recall. Can you tell us are we going to have some problems meeting the standards that they are presently promulgating, or are you unaware of this problem?

Mr. MARES. I am aware of it. There is some technical judgment within our Department that the standards that are being considered by EPA are not as well founded technically as they should be, and we are trying, as professionally as we can, to bring that information into their decisionmaking process in the hopes that they would consider it. If their current proposals were to be adopted, it would cost us some money to come into compliance, and it would, in broad terms, treat this type of risk significantly more stringently than they have treated other types of risks, and that doesn't seem to us a very sensible approach.

Senator DOMENICI. It would seem to me, however, that you probably, from the professional and technical, would have some other facilities and institutions also evaluating because this is not something unique only to emissions that are occurring at Los Alamos Scientific Lab. It has broad application in the country. The same kinds of problems are going to exist for some coal-burning powerplants.

Mr. MARES. Absolutely. You are very well informed. It is a potential problem, and to the extent that we have the technical competence, we are reviewing in the normal way that we do and providing that information to them and try to persuade our sister agency that they should take that into account in making judgments.

Senator DOMENICI. So you'll know our concern, basically we wouldn't like to get surprised 12 or 14 months later with somebody bringing us a big bill saying you are going to have to add a few million to each one of these institutions. We are hard pressed to keep the programs internal to the institutions funded, and if we have to come in with a large amount of money to comply, we surely want to know as early as possible. I think you have to approach them professionally. We can't go in and say we think you're wrong. You have to get experts and we understand that. I assume that's what you are doing?

Mr. MARES. Yes, sir.

Senator DOMENICI. Let's move a minute to the Great Plains gasification project. Could we just ask if for the record the stage of its construction and financial standing?

Mr. MARES. Senator, I haven't checked recently. I am still the departmental officer responsible for it. My recollection is the project is over 90 percent completed. The funding has continued from both the partners of the project and its equity as well as from the government, in terms of lending. They are in the early stages of start up of various systems. They expect to test the gasifiers this month for the first time, and run the first full train in the month of July of this year. The second full train we expect to start up in the month of December of this year.

They have an application before SFC for price support assistance, and I think the schedule at SFC as laid out would lead to reaching agreement in April-May of this spring, with a final agreement by July-August timeframe.

Senator DOMENICI. The full Committee of Environmental and Public Works, we have been dealing with the issue of emergency plans for commercial nuclear powerplants. You are aware that we have a couple that have been very difficult for us in terms of interpreting our own law.

What type of support do you provide to the Federal Emergency Management Agency in their responsibility to implement the emergency procedures at commercial nuclear power plants?

Mr. MARES. We review emergency plans prepared by utilities and advise FEMA regarding our judgment with respect to those plans. We provide technical consultation to FEMA regarding the areas of radiation, and finally we are very responsive in the event of emergencies to make our capabilities available to the authorities that need it. It's one of the reasons I wanted to——

Senator DOMENICI. I don't assume the administration has an official policy with reference to whether or not the Federal Government should take over in an effort to provide the emergency plan in the event local authorities won't? Is there an administration position on that?

Mr. MARES. I don't think an administration position has been formulated on that question. I don't think the question has yet risen to the stage where it was necessary that we do that. I think in each case the States have finally worked their way through an emergency plan.

Senator DOMENICI. We have that very large one that was caught inbetween. It started getting constructed under the old law before Three Mile. We changed the law after Three Mile to mandate emergency as part of the overall licensing if you have to have an evacuation plan. That one had been proceeding with construction prior thereto, and now the local authorities in State and county apparently don't want to do the things that you have to do to develop a plan, which permits them to almost be a local veto over three-fourths constructed multibillion dollar plan, and I don't think we had in mind when we drew the statute providing for local emergency plan, and I just wondered if the administration thought about what their response might be. I am not pressuring you to do that.

Mr. MARES. As I understand it, the proposed emergency plan has been submitted through FEMA, ultimately NRC, and at least has been—you are referring particularly to the Shoreham plant?

Senator DOMENICI. Yes.

Mr. MARES. I think there is some history within the State of New York where a State did in effect take over the emergency plan where a particular county refused to do so. This was in the case of the Indian Point facilities. That point has been made even in the editorials of the New York Times. I think as of this moment the decision is not right from the Federal Government standpoint, and I would rather not speculate on what our position might be; except we do, as you well know, believe that nuclear power is a very important option for this country, and the safety record is outstanding and we should not see that foreclosed to the country.

Senator DOMENICI. In your 1985 budget submittal you indicate that you are completing an assessment of the applicability of the Nuclear Regulatory Commission's division 1 regulatory guides to your category A reactors. How applicable have you found NRC's guidance for commercial power reactors to yours, that is to your test reactors?

Mr. MARES. About half of it has been applicable in areas. For instance, emergency planning, training requirements, emergency shutdown systems, emergency power supplies, things that are related to the operation of equipment have been useful to us.

Senator DOMENICI. Things aren't getting any better over there nonetheless at NRC. You don't have to comment.

I asked them the other day in another committee—I think it is the first time that all five have talked to each other in 6 or 8 months—but in any event, I asked them why they wanted that job, and one of them volunteered right then that he would like to quit. He said, "If I had known what it was about, I wouldn't have taken it." It's a pretty tough job at the Nuclear Regulatory Commission.

We may have some written questions from other Senators. If we do, we ask you to answer them maybe in a week to 10 days. We have nothing further today, and thank you very much for your testimony. We stand in recess.

[Whereupon, at 10:45 a.m., the hearing was adjourned, subject to the call of the Chair.]

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1985

MONDAY, MARCH 12, 1984

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES
Washington, DC.

The subcommittee met, pursuant to notice, at 10:15 a.m., in room SD-366, Dirksen Office Building, Hon. Pete V. Domenici, presiding.

Present: Senators Domenici, Ford, and Levin.

Also present: Paul Gilman, professional staff member; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. WENDELL H. FORD, A U.S. SENATOR FROM THE STATE OF KENTUCKY

Senator FORD [presiding]. Good morning, ladies and gentlemen. Senator Domenici who would be chairing this hearing has called to advise that he will be late, because he is tied up in some budget problems and asks that I go ahead and begin with the testimony, at least the first two witnesses this morning. I will do that with a brief opening statement.

I am pleased that we are holding this hearing of fossil fuels. I am doubly pleased that the fiscal 1985 administration's proposed budget comes a long ways toward the congressional position that fossil energy has to be emphasized as a viable energy option and supported as such by the Government.

Chairman Domenici has taken a leading role over the last several years in keeping the fossil program alive and I thank him very much for that position. I have always felt that we have been missing the boat by not relating clean coal technology to the acid rain problem.

I hope that we can now proceed to make this connection and I congratulate the DOE for its new direction. I look for Congress to continue to correct deficiencies, as we see them in the DOE program, particularly as to this near-abandonment of the gas option. I look forward to this program taking care of that particular deficiency.

With that little opening statement, we would be delighted to hear William A. Vaughan who is the Assistant Secretary of the Department of Energy for Fossil Energy; and then we will hear from Mr. Mares, the Assistant Secretary for Policy, Safety and Environment from the Department of Energy.

Mr. Vaughan, if you would proceed, we will get on with the hearing this morning.

STATEMENT OF WILLIAM A. VAUGHAN, ASSISTANT SECRETARY FOR FOSSIL ENERGY, DEPARTMENT OF ENERGY, ACCOMPANIED BY JAN W. MARES, ASSISTANT SECRETARY FOR POLICY, SAFETY, AND ENVIRONMENT, DEPARTMENT OF ENERGY

Mr. VAUGHAN. Thank you, Mr. Chairman. I would like to submit my more lengthy formal statement for the record and to make a few brief opening remarks before turning to questioning from you and other members of the committee.

Senator FORD. That will be perfectly all right. There will be no objection to your submitting your longer statement in the record.

Mr. VAUGHAN. Mr. Chairman, this is my first appearance before this committee as the Fossil Energy Assistant Secretary. In many ways, however, I am returning to the fossil energy family, particularly the coal side of it.

Prior to joining the Department of Energy, I was the corporate energy manager of one of the world's largest industrial users of coal and I am proud to say that we were one of the leaders within the industry in terms of applying new technological options to the use of fossil fuels.

Now, upon returning to the area of fossil energy, I am equally pleased to return to the challenges and the opportunities offered by research and development. This time, of course, the concepts have a much more distant time horizon and much higher risks of success or failure, and that makes them appropriate, in my judgment, for federally sponsored research.

I might also say that the realignment of the Department joined the Fossil Energy Research and Development Program with the Strategic Petroleum Reserve and the Naval Petroleum and Oil Shale Reserve Programs, thereby consolidating within one organization for the first time, the fossil energy assets of the Department.

The realignment has brought me into contact with a solid group of hard-working research and development professionals. Two of them are seated at the table with me today. On my right is Mr. Don Bauer, my principal deputy, and on my left is Mr. Jerry Walsh, the deputy assistant secretary for management. Others are seated immediately behind me and they are ready to assist in answering your more detailed questions.

To be perfectly candid, Mr. Chairman, I am the new boy on the block with regard to this subject, the fossil energy R&D budget, I did not have the pleasure of putting it together, so I will frequently call upon my colleagues to handle the details if the questions are so directed.

Senator FORD. You sound like a Senator.

FISCAL YEAR 1985 BUDGET

Mr. VAUGHAN. Turning to the fiscal 1985 budget, Mr. Chairman, we believe we have put before you a technologically sound, fiscally responsible, and well-balanced budget proposal.

One of the major themes woven throughout the fabric of this budget is an attempt to address the intent of Congress in proposing a viable, productive, fossil energy research and development program.

As I have stated on page 3 of my prepared, more lengthy statement, when budget proposals differ from congressional appropriations by a factor of three, as they have in the past, programs are in fact disrupted, projects proceed in a stop and start fashion, and the value of the program to the Nation cannot help but be diminished.

We have made a genuine attempt this year to change all that. Now, I recognize that our budget request of some $274 million for fiscal 1985 is still below the level of the fiscal 1984 appropriations. But we have narrowed the gap to something on the order of 15 percent or so. As a result, I believe our discussions this year can focus on fine-tuning the content of our program in a conversational, rather than a confrontational manner.

Another theme in our budget proposal is its consistency with the national energy policy plan. Having viewed fossil energy from the perspective of both industry and now Government, I readily agree with the projections of the policy plan that as much as 75 percent of our energy will continue to come from fossil fuels well into the next century.

It is incumbent upon us, therefore, to position future generations for continued use of these fuels and to do so in a way that does not erode our economy nor compromise our environmental values. That is where new technology comes into the picture.

One of the two strategies of the national energy policy plan is to promote a balanced and mixed energy resource system. Quite simply, we do not have one today. We are still too dependent on those fuels which we have in least supply, and are not enough dependent on those fuels that are most abundant.

If we are going to change that mix in the future, we need to improve the competitiveness of coal in markets that are today dominated by oil and gas. The programs we have proposed in this budget will help us as a nation do that.

Our programs will give industry the technological options that will enable them to view coal in the same competitive light as they presently do oil and gas, from the perspective of handling and transporting it to the perspective of burning it or converting it cleanly and efficiently.

I might say at this point, Mr. Chairman, that there is a strong recognition within this budget that direct combustion will continue to be the dominant use of coal for well into the foreseeable future. That means we must continue to address the fundamental obstacles to coal burning, and those obstacles are primarily environmental.

The theme of environmental compliance runs throughout this budget. For example, programs that can have a direct bearing on reducing acid rain precursors, such as SO_x and NO_x, and particulates, account for more than $57 million of our coal budget or about one-third of it. The comparable funding level for 1984 was just under $37 million and the $20 million increase we are proposing is a major component of the President's commitment as expressed in his state of the Union address to increase acid rain related efforts.

We are not the lead organization in the Federal Government in conducting acid rain research, but we do have the lead role within the Department of Energy to develop potential technological options that industry can use in the future when the need arises.

Let me describe one initiative in particular that is driven by environmental considerations. We have proposed $5.2 million in 1985 to investigate innovative approaches for the control of acid rain precursors in the flue gas of existing coal-fired powerplants.

We are proposing in the fiscal 1985 budget to issue a competitive procurement in the flue gas cleanup area. We want industry to propose ways of cleaning the gases released by coal-fired powerplants, perhaps at a more modest level than is done today, but certainly at much lower costs. The technology would be retrofitted to those plants that are currently not required to install scrubbers, but may have to in the future.

Our rationale is this, today utilities investing in scrubbers have the option of purchasing a system capable of 90 percent sulfur dioxide removal but at a cost of perhaps as much as $900 to more than $1,000 per ton of sulfur dioxide removed.

If legislation is passed requiring older plants, that is those not now governed by recent Clean Air Act amendments to reduce emissions by, say, 50 percent, utilities do not have much choice but to purchase a scrubber that is more effective and much more costly than they really need. Or, they might choose to bypass that convenient nearby high-sulfur coal mine in favor of a low-sulfur mine a thousand miles away. Or, they may shut the powerplant down altogether.

We think utilities need another technical option. So we are looking for scrubber concepts that would offer a minimum of 50 to 60 percent sulfur dioxide control at a maximum cost of $500 per ton of SO_2 removed.

The funding for this procurement, $5.23 million, plus approximately the same amount for the following 2 fiscal years, should enable us to award a minimum of three contracts.

The combustion process itself is another aspect of our program that would receive specific attention in the 1985 budget.

The program has been successful in moving the fluidized bed combustion process into commercial application at moderate industrial scales. Our 1985 budget would continue to improve the competitiveness of this environmentally clean combustion option in the smaller boiler markets where oil and gas now dominate, and in the other end the multihundred-megawatt utility market.

We are continuing efforts in the coal preparation program to upgrade U.S. coals to qualities that would allow them to meet environmental standards with no further controls, or to be used in clean coal-based slurries that could compete with conventional liquid fuels.

We are continuing efforts in coal slurry combustion, as a way of expanding coal's use in oil and gas-fired boilers and furnaces, as well as potentially in gas turbines and diesel engines.

We are maintaining the core research and development efforts in fuel cells, where we believe the phosphoric acid version of this technology is at the point where the private sector can make further investment decisions.

We have proposed a new initiative in the MHD program that hopefully will enable us to move the program toward a logical proof of concept test facility. We are continuing fundamental laboratory and bench scale studies in coal liquefaction and gasification, as well as in oil shale and enhanced oil recovery.

In unconventional gas, we are continuing to conduct research efforts at the multiwell tight sands project in Colorado, as well as establishing a technical data base for eastern shales. We are continuing to investigate novel sources of gas such as hydrates and deep source gas.

In short, Mr. Chairman, our 1985 budget proposal offers us the opportunity to continue advancing the technology of fossil fuels. We believe it is a sound budget and given the fiscal constraints that continue to confront the Nation, we believe it is a responsible one.

With that, Mr. Chairman, I am prepared to answer the questions that you or your colleagues may have.

[The prepared statement of Mr. Vaughan follows:]

STATEMENT OF WILLIAM A. VAUGHAN
ASSISTANT SECRETARY FOR FOSSIL ENERGY
U.S. DEPARTMENT OF ENERGY
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES
MARCH 12, 1984

Mr. Chairman and Members of the Committee:

The Fiscal Year 1985 budget request for the Fossil Energy Program reflects the Department's commitment toward establishing a stable and productive funding profile for coal, petroleum, oil shale, and unconventional natural gas research and development efforts.

The $274.87 million[1/] requested for these activities has been fashioned from three basic principles:

1) Consistency with the National Energy Policy Plan

The budget request is consistent with the primary goal of the 1983 National Energy Policy Plan to "foster an adequate supply of energy at reasonable costs" and the two strategies adopted by the Administration for achieving it: 1) promote a balanced and mixed energy resource system, and 2) minimize federal control and involvement while maintaining public health and safety and environmental quality.

Issued in October 1983, the fourth National Energy Policy Plan was developed at a time when the U.S. energy situation had significantly improved from the price surges and supply shortages that characterized the decade of the 1970s. Total energy efficiency has increased, oil prices have declined, and U.S. vulnerability to disruptions in foreign energy supplies has been reduced markedly.

Yet one fundamental aspect of today's energy situation still closely parallels that of prior years. Fossil fuels -- oil, natural gas, and coal -- continue to account for 90 percent of the energy consumed in the U.S., and the 1983 National Energy Policy Plan doesn't depart substantially from its 1981 predecessor in projecting that as much as 70 percent of our energy will continue to come from fossil fuels well into the next century.

If this future energy pattern is to be achieved without compromising the nation's environmental and economic objectives, the private sector will continue to require a sound base of scientific and engineering information on improved fossil energy concepts. The funding requested for the FY 1985 Fossil Energy program will continue to build this knowledge base.

The FY 1985 budget request follows the two basic strategies for achieving the Administration's energy goal defined in the National Energy Policy Plan:

- to promote a balanced and mixed energy resource system.

During every year of the past three decades, conventional sources of oil and natural gas have accounted for at least 60 percent -- and in some years more than

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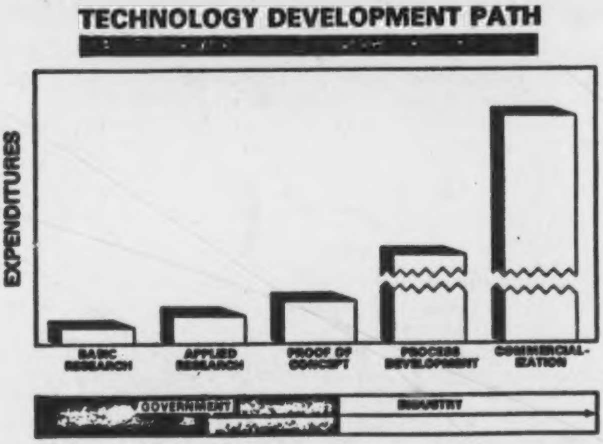
[1/] Funding is for research & development programs and Liquefied Gaseous Fuels Spill Test Facility only. Funding request for Strategic Petroleum Reserve and Naval Petroleum and Oil Shale Reserves is described in separate testimony.

75 percent -- of the primary energy consumed in the U.S. Coal, on the other hand, is currently supplying less than 25 percent of the nation's energy needs. The National Energy Policy Plan's strategy of promoting a more balanced and mixed energy resource system is implemented within the Fossil Energy program by placing a high priority on increasing the competitiveness of coal in markets currently dominated by oil and gas. To achieve this, R&D efforts are focused on improved technologies for direct coal combustion and combustion of coal mixtures and the conversion of coal into liquid and gaseous fuels and feedstocks.

The FY 1985 Fossil Energy program will also emphasize advanced technologies for recovering additional fuels from the large domestic unconventional gas resource and from the currently unrecoverable portion of the petroleum, oil shale and tar sand resources.

o to minimize federal control and involvement in energy markets while maintaining public health and safety and environmental quality;

In this regard, the FY 1985 Fossil Energy budget request continues to emphasize generic or cross-cutting research that is unlikely to result in company-specific proprietary knowledge. It continues to focus the Federal role on the early stages of research and development, i.e., basic and applied research through the technical proof-of-concept (as shown in the following diagram)[2/] which are not likely to attract substantial private sector support without federal involvement:



In addition, the FY 1985 budget request reflects an emphasis on maintaining public health and safety and environmental quality by proposing continued funding for health and environmental studies related to emerging fossil fuel processes, such as coal gasification and liquefaction and oil shale retorting, and by initiating new research efforts directed specifically toward innovative technological options designed to reduce power plant emissions that may be associated with acid rain.

[2/] The stages of the Technology Development Path are defined at the conclusion of this testimony.

2) Continued Emphasis on Federal Spending Controls

The request continues to emphasize the President's commitment to controlling Federal spending as an integral component of the nation's ongoing economic recovery.

The economy is moving into 1984 with a strong momentum that all but ensures a sustained period of real economic growth with an inflation rate roughly half that of three years ago. Yet, federal borrowing continues to subject credit markets to increasing pressures. Throughout the Department, emphasis continues to be maintained on keeping budgets at the minimum levels required to ensure the continuation of viable, productive core R&D programs.

Within the Fossil Energy portion of the budget, substantial emphasis has been placed on private cost-sharing both to facilitate the transfer of technology to the private sector and to reduce federal expenditures. Inherent in the budget request is an attempt to attract research performers which have a long-term institutional commitment to an area of research and to the ultimate application of research results. For example, the FY 1985 request proposes a significant program to construct an integrated, coal-fired magnetohydrodynamic combined cycle system that is contingent upon adequate cost-sharing by the private sector.

3) Accomodation of Congressional Intent

The FY 1985 Fossil Energy budget reflects a genuine attempt to accommodate the intent of Congress regarding the pace of the Fossil Energy program.

As Energy Secretary Don Hodel has stressed in prior budget-related statements, a research and development program, particularly one that emphasizes the early stages of fundamental science and engineering, cannot achieve maximum productivity over the long-term with fluctuating budget levels. In the past, the amount of funds requested by the Administration for Fossil Energy R&D and the final appropriations approved by Congress have differed by as much as a factor of three. The FY 1985 budget attempts to eliminate the "stops-and-starts" that often disrupt multi-year research projects when funding differences of such magnitude exist.

The FY 1985 funding request of $274.87 million[3/] represents a significant increase over the FY 1984 request of $138 million. Although the request is below the level of Congressional appropriations for the FY 1984 Fossil Energy program ($329 million), partly due to the completion of several large pilot plants and process development unit projects, it represents a significant effort by the Administration to reach an accomodation with Congress on the content and level of a technically-defensible Fossil Energy R&D program while meeting the strategies of the National Energy Policy Plan and continuing the Administration's emphasis on federal spending controls.

[3/] Includes $2.0 million for Liquefied Gaseous Fuels Spill Test Facility.

THE FY 1985 FOSSIL ENERGY BUDGET REQUEST

The proposed FY 1985 Fossil Energy budget of $274,870,000 would be comprised of five major components, grouped into two categories:

	FY85 Budget Authority
Coal	$ 177.99 million
Petroleum	31.60 million
Gas	8.55 million
Policy & Management	54.73 million
Research & Development...	$ 272.87 million
Liquefied Gaseous Fuels Spill Test Facility	$ 2.00 million
FOSSIL ENERGY TOTAL......	$ 274.87 million

The $274,870,000 million is derived from five categories of funds:

-- New Budget Authority	$ 204.73 million
-- Unobligated Fossil Energy R&D and Construction Funds from Prior Years	58.84 million
-- Unobligated Alternative Fuels Production Funds from Prior Years	5.80 million
-- Unobligated Energy Production, Demonstration, and Distribution Funds from Prior Years	2.50 million
-- Transfer of Funds from Loan Guarantee Fees collected under P.L. 96-126	3.00 million
Total	$ 274.87 million

The unobligated prior year balances from the Fossil Energy R&D and Construction accounts is made up of unspent funds from the terminated high and low/medium Btu gasification demonstration plant projects, the Solvent-Refined-Coal I and II demonstration projects, the geopressured methane program, and pre-1984 funds from the surface coal gasification, coal liquefaction, and program management accounts. Also included in this amount are $6 million of FY 1984 funds that are expected to be derived from implementing new management improvement initiatives.

The unobligated Alternative Fuels Production funds represent funds remaining in the budget account established under P.L. 96-126 to finance feasibility studies and cooperative agreements for synthetic fuel and certain other alternative energy facilities.

The Energy Production, Demonstration, and Distribution funds remain unspent from the Coal Loan Guarantee program established in 1976 to encourage small operators to open low-sulfur coal mines or build preparation plants. There have been no qualified applicants for this program; therefore, the remaining funds are proposed for use in offsetting a portion of the FY 1985 budget.

A portion of the Loan Guarantee Fees paid by the Great Plains Gasification Associates to the Federal Government for guarantees of obligations issued from the Federal Financing Bank would also be transferred to the Fossil Energy budget to carry out the Department's monitoring provisions of the Loan Guarantee Agreement (see p. 12).

In addition, the FY 1985 budget request includes $15 million appropriated by the Congress during the last fiscal year for federal support of the atmospheric fluidized bed demonstration facility under the administrative and technical direction of the Tennessee Valley Authority. Under provisions of the FY 1984 appropriation language, the funds are to be made available on October 1, 1984, and an additional $15 million is to be made avaiable on October 1, 1985.

The major budget categories within the FY 1985 Fossil Energy request are described in the following pages.

COAL

CONTROL TECHNOLOGY AND COAL PREPARATION

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 27.9	$ 26.0	$ 32.2

The Control Technology and Coal Preparation program takes on added relevance in FY 1985 in light of the National Energy Policy Plan's objectives of fostering a more balanced energy resource system while maintaining necessary environmental quality.

The potential of coal is hindered, in large measure, by its inherent environmental disadvantages. Furthermore, sulfur and other mineral constituents in even the nation's best coals impose cost penalities on all phases of the fuel chain -- in transportation, boiler design and operation, gas cleanup, and waste disposal. The goals of the Control Technology and Coal Preparation activity, therefore, are to develop the technology base to:

- o Upgrade U.S. coals to qualities that allow them to meet environmental standards with no further controls, or to be converted into clean coal-based slurries that could compete with conventional liquid fuels (Coal Preparation)..................$ 11.15 million
- o Improve the capability of removing pollutants from the flue gas of coal combustors (Flue Gas Cleanup)...$ 14.03 million
- o Remove undesirable substances produced during gasification and/or combustion, thus protecting downstream equipment such as turbines and fuel cells (Gas Stream Cleanup)............................$ 4.98 million
- o Provide waste disposal technologies that will comply with environmental regulations without excessive costs (Waste Management).....................$ 2.00 million

Also in FY 1985, the Control Technology and Coal Preparation program will contain significant new initiatives to develop technologies with specific potential for controlling the release of pollutants thought to be contributors to the problems of acid rain (called "acid rain precursors"). Research efforts will focus on:

- o Developing the capability to reduce the emissions of suspected acid rain precursors from existing coal-fired boilers.

This new effort is being carried out within (1) the Coal Preparation program where testing will begin in FY 1985 to determine if advanced physical coal cleaning technologies have the potential for use as acid rain precursor control options, (2) within the Flue Gas Cleanup program where a competitive procurement will be issued to evaluate acid rain precursor control technology at the proof-of-concept scale, and (3) within the Gas Stream Cleanup program where various process modifications might be made to prevent acid rain precursor formation.

COMBUSTION SYSTEMS

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 24.2	$ 18.2	$ 31.7

Like the Coal Preparation and Control Technology program, the Fossil Energy Combustion program is closely coupled to the environmental and balanced energy supply objectives of the National Energy Policy Plan. In prior years, the technological information emerging from this program has led to the commercial introduction of a new combustion option for the nation's industrial sector -- the atmospheric fluidized bed combustor. This technology, now offered within the product line of nearly every boiler manufacturer, offers the environmental advantages of capturing sulfur dioxide and reducing nitrogen oxide formation within the boiler, eliminating the need for expensive scrubbers. More recently, the program has extended its research efforts into technologies with even greater potential including those that would allow coal to compete directly with oil and gas in existing as well as new boilers.

In FY 1985, the Combustion Systems program will focus on activities to establish the technology base for:

- Expanding the application of atmospheric fluidized bed (AFB) combustion concepts (1) into the smaller industrial boiler market through lower cost technology, (2) into the combustion of low-rank coals, and (3) into the utility market; (Atmospheric Fluidized Bed Combustion)..................$ 17.5 million
- Continuing development of the pressurized fluidized bed concept, including continued research at test rigs at New York State University and the General Electric Long Term Materials Test Facility; (Pressurized Fluidized Bed Combustion)..................$ 5.0 million
- Investigating combustion phenomena and other characteristics of coal-based slurries such as coal-water and coal-water-alcohol fuels; (Alternative Fuels)....................................$ 7.2 million
- Developing the means for coal and coal-based mixtures to be fired directly in existing oil/gas designed boilers and process heaters with minimal derating via a precombustion de-ashing step; (Advanced Combustion Technology)..................$ 2.0 million

The major increase in the FY 1985 funding level for the Combustion Systems program compared to FY 1984 is due to the inclusion of $15 million in the Atmospheric Fluidized Bed Combustion activity to support the 160-megawatt EPRI/TVA Utility Demonstration Plant at Paducah, Kentucky. The funding was appropriated in FY 1984 to become available in FY 1985. An additional $15 million would also be made available in FY 1986.

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Also within the Atmospheric Fluidized Bed Combustion program, FY 1985 funds would continue the benchscale testing of the most promising of innovative fluidized bed concepts that could be particularly applicable for smaller (less than 150,000 pounds of steam/hr) applications where oil and gas are now more economical.

Funds have also been requested to support the Pressurized Fluidized Bed (PFB) Combustion program including the PFB test rigs at New York University and the General Electric Long Term Materials Test Facility as well as to support research and data analysis. In addition, funds have been requested in FY 1985 to permit the Department to share the costs of utilizing the PFB combined cycle pilot plant in Wood-Ridge, NJ, if partners can be found in FY 1984 who are willing to participate financially. The Curtiss-Wright Corp., which constructed the pilot facility under a cooperative agreement with DOE, was unsuccessful in securing private sector funding to operate the plant. In the event that the Department is unsuccessful in obtaining cost-sharing partners, the facility would be placed in standby until future needs are determined. In this event, the requested funds would be applied to an ongoing effort to better define the overall R&D needs of PFB technology and to enhance the compilation of a sound technological data base on the PFB concept.

FY 1985 funds for the Alternative Fuels program would complete efforts in coal-water mixture technology research for utility and large industrial applications. Efforts will then be focused on other coal-liquid mixture technologies, such as micronized coal-water slurries mixed with volatile organic compounds.

The funds requested for the FY 1985 Advanced Combustion Technology program would extend the work begun in FY 1984 to develop the means for retrofitting coal-fired combustors onto existing oil- and gas-fired boilers. Research in FY 1985 will focus on the capability of these combustors to prevent molten ash particles, called "slag", from being transported into the boiler (accounting for the name "slag rejecting" combustors), on reducing sulfur dioxide and nitrogen oxide emissions, and on increasing the capability to burn a variety of coals. The FY 1985 program should establish the economic competitiveness of these retrofit combustors for utility and large industrial boilers. Additionally, funds are requested to advance through benchscale testing the most promising of several innovative concepts potentially applicable to smaller boilers.

HEAT ENGINES

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 5.1	$ 6.5	$ 7.7

While the Combustion Systems Program is focusing on the use of coal and coal slurries in boilers and process heaters, the Heat Engines program is directed towards the longer-term goal of utilizing advanced coal slurries or gaseous fuels in gas turbine and diesel power systems currently powered with distillate fuels or natural gas.

The ultimate goal is to develop a technology base to permit the private sector to assess the commercial viability of coal-fueled power conversion systems. The DOE program's principal purpose, therefore, is to:

o Establish basic component cooling, component materials, combustion, and coal-slurry quality data necessary for firing coal slurries in gas turbine power conversion systems	$ 4.4 million
o Establish basic design, combustion, materials, and fuel interaction and related data for coal slurry firing in diesel power generating systems.........	$ 1.7 million
o Continue laboratory research to interpret engineering test data and resolve fuel and design uncertainties..	$ 1.6 million

In both the turbine and diesel areas, FY 1985 funds would be used to select reference fuel specifications that are needed to make engineering evaluations of critical component or engine designs. Preliminary testing would also begin on selected turbine components and diesel engines designs.

COAL LIQUEFACTION

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 37.6	$ 28.9	$ 13.9

Although current projections (including those of the National Energy Policy Plan) do not point to large price increases in the relatively near future, in the long term, particularly as we move into the next century, the lowest cost energy supply as well as our national economic and security interests may dictate that synthetic fuels, including liquids made from coal, be substituted increasingly for conventional oil and natural gas.

To establish a sound, long term and effective synthetic fuels capability, industry will need to develop lower cost, more efficient liquefaction technologies which can utilize the U.S. coal resource base. The FY 1985 Coal Liquefaction Program, therefore, would continue to:

o Provide data on improved indirect liquefaction technology that can utilize synthesis gas produced by modern gasifiers with a minimum of downstream processing; (Indirect Liquefaction)............	$ 2.5 million
o Aid the development of more advanced direct liquefaction processes that could produce 10 to 15 percent higher, improved quality yields than earlier methods with cost improvements approaching 30 percent; (Advanced Process Development).............................	$ 5.6 million
o Provide engineering analyses, data base management, and investigation of key instrumentation/component requirements (Support Studies/Engineering Evaluations).................	$ 5.8 million

It is generally agreed that any significant use of coal liquefaction will probably not occur before the turn of the century. Therefore, the FY 1985 budget request continues to be refocused on longer-range, laboratory scale projects that could lead to a new generation of liquefaction technologies. Also, both the Methanol-to-Gasoline project (Federal Republic of Germany) and the Liquid Phase Methanol Synthesis project (LaPorte, Texas) are now operating and expected to continue test runs through at least part of FY 1985. Funds are sufficient from prior years to carry out the currently planned test operations at these two indirect liquefaction facilities.

In FY 1985, indirect liquefaction research will continue at laboratory scale and with private sector participation to develop new and improved catalytic synthesis technology.

In the direct liquefaction area (termed "Advanced Process Development"), DOE-sponsored research at the EPRI/Southern Company-owned advanced concepts liquefaction test facility at Wilsonville, Ala., will be concluded by December 1984, and no additional funds are requested in FY 1985. Benchscale activities will also have been concluded in 1984 on new methods for direct catalytic liquefaction and innovative concepts involving slurry oil composition and preheater/prereactor performance.

Technology base activities will continue in FY 1985 in catalyst research for direct liquefaction, including slurry phase catalysts for liquefying low rank coals. Laboratory scale investigations will also be conducted on new direct liquefaction process concepts that could offer further reductions in capital costs and improved process operability. Most of this work will be conducted in-house, along with one industrial contract scheduled to be awarded by competitive solicitation in FY 1984.

Funding has been added in the Liquefaction Budget in FY 1985 for data base management to ensure that information from previous projects and modeling studies is captured and made useful and available to industry. Also within the Support Studies activity, additional efforts will be conducted in FY 1985 to characterize the biochemical nature of products from advanced liquefaction concepts, such as two stage liquefaction. Chemical upgrading studies will also be undertaken.

SURFACE COAL GASIFICATION

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 38.8	$ 36.8	$ 15.0

Coal gasification has become the first of the coal-based synthetic fuel options to reach modern-day commercial application. Through gasification, coal can be used for manufacturing low/medium Btu fuel gases for industrial and electric utility uses as well as synthesis gas as feedstocks for chemicals or liquid fuels or for upgrading into high-Btu pipeline quality synthetic natural gas. Industry has taken significant strides within the last year to advance commercial gasification technology. In addition to several smaller, on-site gasifiers, four large commercial-scale gasifier concepts are now operating or are in the final stages of construction in the U.S.:

- Fourteen 1000-ton per day Lurgi fixed-bed gasifiers at the Great Plains Coal Gasification Plant under construction in North Dakota (12 of which will operate during full production with two kept on standby);
- Four 900-1000 ton per day Texaco entrained bed gasifiers, two of which are now in operation at the Tennessee Eastman coal-to-methanol facility in Kingsport, Tenn., and two which are being installed at the Cool Water gasification/combined cycle plant under construction at Daggett, Calif.;
- A 600-ton per day KilnGas horizontal rotating gasifier now in startup at the Wood-River Power Station near Alton, Illinois; and
- An 800-ton per day Dowsyn entrained bed gasifier now in operation at Dow Chemical Company's demonstration unit in Louisiana.

With commercial experience now being generated in the U.S. from operating or soon-to-be-operating full-size gasifiers, the Department's FY 1985 Surface Coal Gasification budget request is again emphasizing more generic studies to improve the fundamental understanding of gasification principals and the total gasifier system. In carrying out this program, the FY 1985 budget request would:

o Establish a comprehensive technology data base for new gasifier concepts and gasification systems integration, including process fundamentals, new waste water treatment techniques, computer modeling, and basic data on kinetic and fluid dynamics, thermochemistry and process chemistries; (Advanced Process Development)	$ 4.45 million
o Continue development at small scales of hybrid gasifiers, determine methods to optimize the gasification system and associated process units, and develop the engineering data needed to increase the gasification facility's efficiency and reliability by improving components, instrumentation and control techniques, and applying new material technologies; (Systems Engineering Concepts)	$ 3.98 million
o Produce technical and environmental assessments and engineering evaluations associated with gasifier concepts and systems; (Environmental and Engineering Analyses)	$ 3.56 million

While large scale gasification pilot plants and process development units that have been funded in the past will be completed prior to FY 1985, the core gasification program will maintain a significant effort to build upon and improve the data base now being developed in the U.S.

Within the Advanced Process Development budget request, a large number of tests will continue to be run at the Advanced Gasification Test Facility located at the Morgantown (WV) Energy Technology Center. This facility, which houses small, laboratory-scale fluid and entrained bed gasifiers, provides a highly flexible test bed for studying the gasification process as operating conditions are varied. This data will be used to confirm the kinetic and thermodynamic assumptions used in several modeling codes being considered for use in the gasification technology data base.

A study of "hybrid" reactors which would link gasification and combustion processes would begin in FY 1985 under the proposed funding request for Systems Engineering Concepts. This concept would incorporate within the gasifier the capability to process feedstocks such as beneficiated coals and/or gasify coal in a manner particularly suited to produce the optimum product (liquids, chars, and gases) tailored to a more sophisticated marketplace.

Within the Environmental and Engineering Analyses budget request, studies will continue on gasification plant environments, fugitive emissions, and effects on workers of accidental exposures to plant waste streams. Also in FY 1985, work will continue to upgrade the ASPEN computer model which has the potential of becoming an extremely effective tool for storing, evaluating, and using a wide spectrum of gasification technology data.

In early FY1985 (December 1984), the Great Plains Coal Gasification plant is scheduled to begin full production of 125 million cubic feet per day of synthetic pipeline quality gas. The start-up and operation of this $2.1 billion pioneer facility will represent a significant step forward in developing a synthetic fuels capability that would be available should future market forces dicate an expansion of the nation's synfuels industry. The Energy Department remains the responsible agency for:

o Managing the Federal loan guarantee and monitoring of the project (Great Plains Coal Gasification Project)	$ 3.0 million

The Great Plains plant, in addition to being a "first-of-a-kind" commercial venture, also offers significant opportunities for selected research and development activities. In addition to the loan guarantee management and monitoring funds identified above, the Department also proposes to use FY 1985 funds from its Surface Coal Gasification program to (1) initiate slip stream testing at the Great Plains plant to study the performance of instruments, operating components, and construction materials (using funds from the Systems Engineering Concepts account); and 2) apply the commercial operating data that will become available as the Great Plains project starts up to upgrade the ASPEN computer model (using funds from the Environmental Studies and Engineering Analyses account).

UNDERGROUND COAL GASIFICATION

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 6.00	$ 6.00	$ 5.85

More than a dozen field tests to determine if subbituminous coal seams could be gasified underground have produced an extensive data base which should allow industrial groups to design the next logical step -- tests to validate the concept in 10-40 ft. thick flat-lying subbituminous coal seams. Accordingly the Federal government's program has been redirected to develop gasification concepts more applicable to less favorable coal resources such as higher ash or swelling coals. To carry out this program, FY 1985 funds are requested to:

o Investigate environmentally acceptable in situ technologies for converting less desirable coals, such as high-ash subbituminous coals and high-sulfur bituminous coals, into synthetic gas suitable for direct use or for conversion to higher quality products (Gasification Technology Development)	$ 3.15 million
o Ensure that the necessary post-burn environmental monitoring of past sites is conducted according to state requirements and that long-term research is continued in the cleanup of contaminants left following underground gasification (Environmental and Advanced Research)	$ 2.70 million

A significant addition to the underground gasification data base was made last year when a partial seam test of the novel Controlled Retracting Injection Point ignition technique was completed in a subbituminous coal bed in the State of Washington. Assuming favorable preliminary post-burn analysis of this initial field test, funds from the FY 1985 budget would be used to conduct a logical follow-up test that would encompass greater coal thickness, techniques to increase burn width, and other improvements. The costs of such a test would be shared by industry.

In addition, efforts will continue in FY 1985 to broaden the underground coal gasification data base to include high-sulfur bituminous coal. Characterization of a selected coal site will be completed in FY 1985 along with the design of outcrop tests that would give the necessary information to design the first underground test.

The existence of old underground gasification test sites, principally in Wyoming, afford a unique opportunity to study the effectiveness of physical, chemical and microbiological cleanup of contaminants left following gasification. The FY 1985 budget would provide funds for the Western Research Institute (formerly the Laramie Energy Technology Center) to continue this long-term research.

FUEL CELLS

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 29.9	$ 42.6	$ 13.7

Funds for the FY 1985 Fuel Cell program are being requested to continue the technology base program. The 40-kilowatt field test project and the 4.8-megawatt demonstration project in New York City are fully funded and are not anticipated to require FY 1985 funds. The phosphoric acid fuel cell development activities have progressed to the point where the private sector can assume a greater financial role in moving the technology into commercial application.

As a result, the Federal funding request is being reduced in the phosphoric acid fuel cell program. Funding would also be reduced in the molten carbonate development program due to reduced emphasis on the test verification of individual fuel cell stacks. This is a result of continuing difficulties in cell designs and materials and the requirement to resolve these more fundamental problems before proceding to multiple stack fabrication and verification. The Department will also attempt to acquire additional private sector cost sharing for molten carbonate technology development.

A portion of the reduction in funding from FY 1984 to FY 1985 is also due to the recent transfer of the Thermionics program, which had been funded under the Advanced Concepts portion of the fuel cell program. This activity will now be conducted by the Department's Office of Nuclear Energy.

The fuel cell program incorporates significant private sector involvement focused on commercialization, engineering activities, and a portion of the technology base development. Government support is focused on the higher risk cell and stack technology development. In FY 1985, the Fuel Cell program proposes to address:

o Continued development of the phosphoric acid technology for electric utilities and for on site applications (Phosphoric Acid Systems)	$ 7.20 million
o Continued development of molten carbonate power plant system technology for both utility and industrial cogeneration applications (Molten Carbonate Systems)	$ 4.10 million
o Continued development of the solid oxide fuel cell (Advanced Concepts)	$ 2.40 million

The technical feasibility of phosphoric acid fuel cells has been demonstrated by the operation of several preprototype systems and benchscale tests of new cell designs. In 1983, a U.S.-built experimental utility-sized, phosphoric acid fuel cell went into service in Japan and a 4.8-megawatt unit based on an earlier design is expected to start up in the U.S. in 1984. The first 40-kilowatt onsite fuel cells are now being installed at commercial sites across the country.

With this activity underway, the FY 1985 funding request would be targeted toward a more advanced, potentially more economical phosphoric acid concept that would employ larger area cells. Funds would also be provided to continue work on an air-cooled phosphoric acid concept suitable for electric utility applications and to continue technology development of smaller, on-site systems.

FY 1985 funding in the Molten Carbonate program would be directed at fabricating and testing the first full area, 20-cell short stack and verifying the suitability of cathode materials. Also in FY 1985, the concept of reforming fuel internally in the fuel cell should be verified and data will be available to decide the merits of proceeding with stack development.

The solid oxide fuel cell concept will also be tested in FY 1985 to determine if a 5-kilowatt preprototype module can operate as predicted using coal gas as a fuel. Technology base efforts on the solid oxide concept will also be continued within the requested FY 1985 funding levels

MAGNETOHYDRODYNAMICS

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 29.0	$ 30.0	$ 17.8

The FY 1985 budget request includes a proposed realignment in the Magnetohydrodynamics (MHD) Program. A key feature of the new initiative is a requirement for significant cost-sharing by the private sector that should facilitate the proof of concept of MHD technology and provide a clear indication of the private sector's view of MHD's future commercial potential.

The proposed FY 1985 MHD program would be comprised of two elements:

o a scientific research program focused on resolving key technical issues; (Scientific Research)..............................	$ 10.8 million
o an engineering effort initiating the design, construction and operation of a cost-shared MHD combined cycle proof of concept system; (Integrated Test Facility)..........................	$ 7.0 million

The MHD scientific program will focus on the fundamental technical problems that must be resolved in order to establish the required technology base for the second phase of the proposed program. For example, information will be developed on (1) the recovery and regeneration of potassium seed material required to render the hot coal gases electrically conductive; (2) on major subsystems such as coal combustors where, for example, erosion and corrosion rates need to be quantified and hardware developed to ensure continuous slag rejection; and (3) on the design and operating conditions required to ensure that ash buildup in the bottoming cycle does not hinder effective heat transfer.

Concurrently, the second phase of the proposed MHD program provides a basis for industry participation and cost-sharing (targed on the order of 50 percent) to design, construct and operate a coal-fired MHD combined cycle proof of concept test unit. The proposed plant would integrate each major component of the power system -- combustor, channel, superconducting magnet, inverter, and heat recovery/seed recovery and regeneration system. The test facility would be sized at an approximate scale of 80 megawatts (thermal input), sufficient to give private industry the information it needs to make future commercial development decisions.

A plan describing the proposed program will be sent to the Congress in early 1984.

Should significant industry cost-sharing not be available, the program schedule would be adjusted accordingly. If no cost-sharing is available, the $7 million funding level requested for FY 1985 would be proposed for use in terminating efforts at the Component Development and Integration Facility in Butte, Mont., and at the Coal-Fired Flow Facility in Tullahoma, Tenn.

ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 31.65	$ 39.25	$ 40.27

The Administration's commitment to more fundamental science and technology is reflected in the Advanced Research and Technology Development budget, a cross-cutting function that includes activities underlying the entire spectrum of coal-related programs.

This budget item provides a focal point for government involvement in activities directed toward, for example, developing a better understanding of the basic chemical mechanisms of synthetic fuel production, expanding the knowledge base on the properties of fossil fuel liquids, improving the understanding of coal combustion and the behavior of materials, components and instruments, and exploring new materials, catalysts and electrolytes for fuel cell systems.

To carry out these research efforts, funding for the Advanced Research and Technology Development activity is organized to:

o Conduct small scale, fundamental studies of phenomena associated with coal science, liquefaction and gasification; (Processes)	$ 10.03 million
o Study the fundamental mechanisms involved in the utilization of low rank coals, chars, beneficiated coals, coal-liquid mixtures, fuel cell and coal-based feedstocks; (Direct Utilization)	$ 10.16 million
o Develop a generic technology base for materials used in a variety of fossil energy systems and develop a better understanding of the effects on components of solid materials in fossil energy process streams; (Materials and Components)	$ 8.06 million

- Conduct environmental related studies, technical and economic analyses, technology base synthesis, instrumentation, control, and diagnostics; (Technology Crosscut)................................$ 7.53 million

- Provide competitively-awarded grants to universities for fundamental projects and student/scientist training (University Coal Research).................$ 4.50 million

Within the Processes portion of the FY 1985 Advanced Research and Technology Development program, a new research effort will be initiated to develop biological approaches to coal liquefaction and to apply new and evolving catalyst concepts, such as cluster catalysts, to coal liquefaction.

Scientific investigations of the properties of coal and coal based fuels prior to combustion will continue in the Direct Utilization portion of the budget request. Also included in the category will be continued fundamental investigations of coal combustion typical of advanced fossil energy concepts, of erosion, corrosion, and deposition resulting from the ash and mineral matter found in all coals, and of separation mechanisms that could remove pollutants and other impurities from hot coal gas streams. Generic fuel cell research will continue to be conducted, and funds will continue to be provided for the IEA-sponsored coal science initiative.

Structural ceramics and ceramic composites will be one of the areas of research to be funded in FY 1985 under the Materials and Components portion of the budget, along with specific efforts focused on the way in which refractory linings in gasifiers and boilers deteriorate under typical operating conditions. The development of specialized components for fossil energy systems and research into bulk solids flow and solids transport are also areas of research within this budget category.

The Technology Crosscut funding request will provide for strategic planning efforts that support the development of Fossil Energy R&D priorities, allow a higher level of participation by the Office of Fossil Energy in the Interagency Task Force on Acid Precipitation, and provide funds for two coal research services operated under the auspices of the International Energy Agency.

Approximately 20 new university research programs would be initiated with the funding provided in the University Coal Research program budget for FY 1985. This activity has attained significant stature in the academic community and is building a valuable national resource of new ideas and knowledge related to fossil energy within the nation's university system.

PETROLEUM

ENHANCED OIL RECOVERY

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 6.5	$ 9.2	$ 13.4

The Department's recognition that liquid fuels are a mainstay of our economy is reflected in the increased funding levels requested for Enhanced Oil Recovery. Nearly two barrels of petroleum out of every three discovered -- a total of as much as 312 billion barrels -- may remain unrecoverable given today's oil prices and limitations of current oil production technology. New concepts and processes will have to be developed if the nation expects to produce significant quantities of oil from these currently unrecoverable resources.

The Department has projected that 18 to 54 billion barrels could be added by current enhanced recovery techniques compared to the nation's known reserves of 28 billion barrels. Yet even that amount would still leave 259 billion barrels in the ground. Only with a fundamental understanding of the mechanisms at work in the geochemically and geologically complex underground oil reservoirs can more efficient, higher recovery processes be developed for these currently unrecoverable resources.

While the private sector has undertaken significant efforts to develop and apply various enhanced oil recovery techniques during the past three decades, actual results have been mixed. None of the processes are well understood, and this has restricted enhanced oil recovery production to relatively simple methods. Moreover, the use of simple, low risk, low efficiency enhanced recovery techniques to recover only a marginal fraction of the oil reduces the reservoir saturation and in all likelihood, renders the reservoir unattractive for further recovery efforts even using novel processes.

The focus of the Department's program, therefore, is based on obtaining a clearer understanding of the scientific processes which govern the behavior of a wide array of enhanced recovery technologies. Specifically, the Enhanced Recovery Program in FY 1985 will focus on:

o Fundamental research into the behavior of light oil enhanced recovery processes such as micellar-polymer and carbon dioxide flooding; (Light Oil)	$ 9.20 million
o Developing a better understanding of heavy oil recovery processes such as steam flooding and in situ combustion; (Heavy Oil)	$ 3.00 million
o Evaluating and developing new concepts for in situ recovery of bitumen from U.S. tar sand deposits (Tar Sands)	$ 1.20 million

Improved recovery efficiency for light oil could add from 12 to 23 billion barrels to domestic crude oil reserves. The Department's FY 1985 funding request in this area will increase efforts in fundamental research, data base development and dissemination, and analyses of previously completed tests on enhanced recovery processes. It will also permit some post-test analyses of several projects begun in the late 1970s under the Economic Regulatory Administration's incentive program. One of the products of the Light Oil research effort is a detailed reservoir data file containing over 3500 reservoir descriptions. This file will continue to be expanded in FY 1985 to provide information essential to policymakers and petroleum companies in evaluating the potential for enhanced oil recovery.

The nation's heavy oil resources exceed 100 billion barrels, nearly one-third of the total existing U.S. petroleum resources. The Department's FY 1985 funding request for heavy oil research will increase the level of research into the behavior and mechanisms of heavy oil processes. Working in the laboratory, researchers will study the effects of adding selected chemicals to steam to improve recovery efficiency and examine the kinetics of in situ combustion in representative heavy oil reservoirs. The effects of injecting combustion gases created during the steam production process into the reservoir to aid recovery will also be studied. Work will also continue jointly with Venezuela and Mexico to investigate technical problems associated with producing and upgrading low-quality, heavy crude oils.

Although a recent study of U.S. tar sands revealed that the nation has more tar sand resources than previously thought -- 54 billion barrels compared to the previously estimated figure of 36 billion barrels -- no commercial production project has yet been successful in this country. The U.S. resource base, with few exceptions, is too deep for conventional mining, therefore the Federal research effort will continue to concentrate on various in situ processes. In FY 1985, in situ combustion methods will be studied along with techniques that inject hot fluids into the reservoir. Novel mining concepts will also be examined to determine their potential in recovering a portion of the nation's tar sand resource, and a series of environmental research activities focusing on both air and water quality impacts of tar sand production will be conducted.

The FY 1985 funding request will also enable the U.S. to continue the exchange of technology with Venezuela and Canada, both of whom are pursuing heavy oil and tar sands technology.

OIL SHALE

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 12.3	$ 16.2	$ 12.0

With an oil recovery potential that exceeds the reserves of all of the Middle East, U.S. oil shale deposits represent a significant national resource. In 1984, the first modern-day commercial shale oil production plant -- the Union Project in Colorado -- is expected to begin full-scale operations, and several other projects backed by the U.S. Synthetic Fuels Corporation are expected to move into more advanced stages of design or construction.

The Federal research program has turned its attention in recent years to more fundamental technology research particularly in the areas of shale fracturing, novel concepts, and environmental mitigation. These efforts would continue in FY 1985 under the proposed funding levels with some further changes in the scope of some of the projects. Specifically, the Department's FY 1985 Oil Shale program would continue to:

o Develop the technology base needed to support private sector efforts to improve shale oil technology; (Technology Base)..	$ 6.0 million
o Obtain environmental data on the impacts of oil shale development and devise methods to mitigate the environmental impacts of emerging technologies; (Environmental Mitigation)..............................	$ 6.0 million

The planned activities for FY 1985 are generally in accord with a 5-year research and development plan for the chemistry and physics of oil shale retorting that was developed in FY 1983. Ongoing work in the Technology Base activity will continue in FY 1985 to apply sophisticated analytical techniques to measure the chemical makeup of retort gases, thereby providing an indication of retorting conditions (previous analyses had focused only on shale oil production measurements to determine reaction kinetics). Studies of the kinetics of coking and oil degradation near the retorting zone will also be conducted to provide information for computer models currently being developed. In FY 1985, research to develop kinetic expressions will be used to assist in developing a model that could help predict the behavior of the various chemical constituents of oil shale in an indirectly-heated retort.

The oil shale technology research program was extended in FY 1983 and 1984 to encompass the shales found in the eastern U.S., and certain novel techniques, such as fluid bed retorting, were found to increase substantially the yields of liquid product from these lower grade shales. In FY 1985, research to study the environmental emissions from fluidized bed retorting and combustion will be supplemented by kinetic and modeling studies.

Although no large scale experiments are planned, the FY 1985 budget request includes funds to refine the present rock fragmentation models. Several large scale explosive fragmentation tests have been conducted under previous budgets, and a significant quantity of unprocessed data exists. The FY 1985 effort, therefore, will concentrate on evaluating and processing this data into a more useable form.

Oil shale air emissions and water effluents have a chemical and biological nature that may preclude, in some cases, the use of existing environmental control devices. If an oil shale industry is to develop to its full potential in the future, therefore, a better understanding of the chemical constituents of these materials is needed. The FY 1985 proposed program in Environmental Mitigation would continue to provide this important, fundamental data. X-ray methods will be applied to determine the differing chemical structures of sulfur released in retorting gases, and if feasible, similar methods will be applied to analyses for arsenic, selenium, and cadmium. Mass spectrometry will also play a key role in the FY 1985 program to study trace sulfur compounds and the chemical mechanisms by which they are produced. Limestone scrubbing of sulfur dioxide may be one way of controlling air emissions from future eastern shale oil production plants, and the FY 1985 budget proposes to initiate studies of this technique.

Mathematical descriptions of the kinetics of raw shale processing are also important in controlling emissions, and work will begin in FY 1985 to obtain more accurate information in this area, including the extension of studies from carbon dioxide and sulfur dioxide release to the formation of nitrogen oxides and hydrogen. Studies of the chemical makeup of spent shale as it relates to the retorting process are also planned in FY 1985 using both conventional and newly-developed analytical techniques.

Health effects studies are also a major emphasis in the FY 1985 proposed program, and a specific effort will be focused on identifying specific mutagenic compounds in shale oil and determining the manner in which they are produced. Research that will help determine the makeup of retort process water along with environmentally safe ways of disposing of it, including co-disposal with spent shale, will also be funded in FY 1985.

ADVANCED PROCESS TECHNOLOGY

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 5.0	$ 5.0	$ 6.2

Crosscutting fundamental research for petroleum and gas technology is contained in the Advanced Process Technology activity. This area is divided into two major components with objectives of:

o Investigating novel extraction technology, fundamental chemistry, and environmental research; (Advanced Exploratory Research)................	$ 4.5 million
o Conducting Arctic-related research and maintaining a publicly-acessible data base; (Arctic and Offshore Research)................	$ 1.7 million

Within the Advanced Exploratory Research program, work will be expanded moderately in FY 1985 to study the novel use of micro-organisms to enhance oil recovery with the most promising techniques to be advanced into small scale field testing.

Fundamental petroleum chemistry research will continue, along with continued efforts to characterize hydrocarbon reservoirs and develop advanced instrumentation. Environmental related research will cover all aspects of the liquid fossil fuel cycle, from extraction to processing to utilization, and will include methods for mitigating aquifer damage and ground subsidence. Laboratory research will also investigate techniques for removing unstable and toxic organic substances from fossil liquids and gases. Studies of fuel/engine interactions will continue with results expected to help determine the extent of air pollutants released when various fossil-derived liquids are combusted. In this way, processing techniques for reducing potential pollutants before they reach the engine can be developed.

The Arctic and Offshore Research program began in FY 1983 as an effort to bring together the information being generated by a variety of Federal programs and to determine where gaps existed in the publicly-accessible data base. Within the Department, basic research efforts will be conducted in FY 1985 to add to this data base. In particular, studies will be conducted on the potential effects of extreme Arctic conditions on drilling and production operations. These studies will focus on ice ridges and islands, the effects of permafrost, and the stability of the seafloor in offshore resource areas.

GAS

UNCONVENTIONAL GAS RECOVERY

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 13.7	$ 15.5	$ 8.6

The completion of several reserve estimates, site characterizations, and a number of field experiments, plus the elimination of activities in the geopressured methane program, result in a reduction in proposed funding for the FY 1985 Unconventional Gas Recovery program. Several activities, however, which will assist the private sector in developing cost-effective technologies required to produce gas from the nation's unconventional gas resources, will continue in FY 1985. Major objectives of the program include the development of:

o A technical data base for the Devonian shales of the Appalachian, Illinois, and Michigan Basins; (Eastern Gas Shales).................	$ 1.5 million
o A technical data base for the low-permeability gas sandstones in the Piceance (Colorado), Uinta (Utah), Great Plains (Montana, North Dakota) and Greater Green River (Wyoming) Basins; (Western Tight Sands)..................................	$ 4.8 million
o Information on novel unconventional gas resources and environmental assessments; (Environmental and Advanced Research)................	$ 2.3 million

The funds requested for FY 1985 in the Eastern Gas Shales area will be used principally to support a test in southern Kentucky that will verify certain reservoir properties, such as flow rates, permeabilities, fracture spacings, etc. The funding request would also continue the acquisition of similar data from various locations within the eastern shale region and the integration of this data into a shale data base. Work would also continue in model development and rock mechanics.

As in past years, the Western Tight Gas Sands activity is focusing on the lenticular, or lens-shaped, sandstone reservoirs which are much more difficult to characterize and produce than the so-called blanket sands that have attracted the most private sector interest. Initial fracturing began at the Multiwell Test Facility in Colorado in FY 1984 and will continue in FY 1985. Generic supporting research, including efforts in geology, fracture mechanics, and modeling, along with work in diagnostics would also continue in FY 1985.

Two new potential gas resources -- methane hydrates and deep source gas -- have attracted interest in the last few years, and funds requested within the Environmental and Advanced Research program will continue to evaluate the long term potential of these resources. Except for a methane hydrate core recovered off the coast of Guatemala in 1981 (a portion of which is now being analyzed by DOE), the dimensions and properties of naturally occurring methane hydrate concentrations and the potential and economics of producing them is unknown. Similar uncertainties surround deep source gas which is thought to be produced by abiogenic means and/or possibly through the transport of organic materials beneath the earth by the movement of tectonic plates. The FY 1985 program will continue efforts to resolve some of the existing uncertainties, yet complete and definitive answers are still several years in the future.

The Environmental and Advanced Research program also includes funds for technology base studies of coalbed methane stimulation and modeling and for environmental assessments required for all field experiments.

Congress appropriated funds in FY 1984 to conduct aspects of a geopressured methane research program within the Fossil Energy program. Historically, this program had been managed by the Office of Conservation and Renewable Energy, and a review by the Department has indicated that this activity should continue to be managed by the Conservation program. Therefore, no funds are being requested for it in FY 1985 as part of the Fossil Energy R&D program and the FY 1984 funds appropriated to the Office of Fossil Energy have been proposed for deferral.

POLICY AND MANAGEMENT

As Congress directed, the FY 1985 budget consolidates funds for salaries, benefits and travel for the Headquarters organization and overhead/indirect field center expenses. It also provides centralized funding of capital equipment and construction needs. This budget item, therefore, contains three major components:

o Program Direction funds for Headquarters and Energy Technology Centers/Project Offices (Management Support).................................	$ 45.2 million
o Capital Equipment (Institutional Investment)..	$ 4.5 million
o General Plant Projects (Construction)....................	$ 5.0 million

The Management Support budget request provides for 127 fulltime (equivalent) positions at the Fossil Energy headquarters, and therefore, assumes that Congress will repeal the currently legislative-mandated minimum employment level of 150 fulltime equivalent positions. (In the interim, the Department will comply with the legislative requirements.) The funding request also supports the indirect costs of the Pittsburgh (PA) and Morgantown (WV) Energy Technology Centers and the Project Offices in Bartlesville (OK), Laramie (WY), and Grand Forks (ND). The program direction funds are divided between Headquarters and the field as follows:

Headquarters Program Direction......................	$ 7.9 million
ETC Program Direction.................................	$ 37.3 million

The Institutional Investment budget request would permit the field centers, including National Laboratories, to upgrade their analytical equipment. A significant portion of these funds will be used to increase the capacity of the data processing center at the Morgantown Energy Technology Center.

The Construction account would provide funds for several general plant projects needed, for example, to meet OSHA health and safety requirements, repair boilers, and other structures, provide equipment storage facilities, and renovate certain facilities to enable more efficient use of existing space. Also included are funds to complete the waste water treatment facility at the Morgantown Energy Technology Center.

LIQUEFIED GASEOUS FUELS SPILL TEST FACILITY

(Budget Authority in Millions)

FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
$ 3.5	$ 3.3	$ 2.0

The Liquefied Gaseous Fuels Spill Test Facility is a new addition to the Fossil Energy budget with funds provided in the DOE Biological and Environmental Science program budget prior to FY 1985. This facility, proposed for construction on the Nevada Test Site, will provide safety and environmental control information on such liquefied gases as liquefied natural gas, liquefied petroleum gas, chlorine, and ammonia. Dissemination of this information to industry, regulatory agencies, and the general public, and its subsequent application, is expected to reduce the frequency of accidental spills and to mitigate the consequences of such spills when or if they occur. Three specific objectives make up this program:

- To develop and validate models of LGF release behavior in sufficient depth to provide a firm technical foundation for promulgating regulations and to adequately support the development of release prevention and control techniques;

- To investigate and validate methods for preventing accidental spills;

- To investigate and validate methods for controlling the consequences of accidental spills.

The spill test facility to be constructed in FY 1984 consists of pressurized tanks, dewars, foundations, piping, control systems, berms, provisions for a future spill pond, an access road and utilities. A portion of the instrumentation, data acquisition systems, large storage tanks, and computer accessories have already been purchased by the federal government.

When the test facility becomes operational in FY 1985, it will be capable of producing spill rates of up to 100 cubic meters per minute with quantities of up to 200 cubic meters. As various liquefied gaseous fuels typical of those found in commerce are released, instruments will measure such characteristics as dispersion, rapid phase transition, pool fire and vapor burn phenomena.

FY 1985 funding will be used to complete fabrication and begin checkout tests of the facility. These activities will include the development of approval processes and procedures for environmental documentation of future tests. The funds will also be used to develop the information necessary for obtaining State and other required permits, and for performing safety analyses to assure personnel and equipment safety.

Checkout tests at the facility in FY 1985 will be financed by federal funds, however, the Department will make the facility available in future years, on a user fee basis, to private firms and other federal, state and local government agencies to sponsor their own tests.

Although included within the Fossil Energy program, which derives its research and development funding from the Interior and Related Agencies Appropriations Act, funds for the Liquefied Gaseous Fuels Spill Test Facility are requested to be provided from the Energy and Water Appropriations Act.

DEPARTMENT OF ENERGY
FY 1985 CONGRESSIONAL BUDGET REQUEST
SUMMARY OF ESTIMATES BY APPROPRIATION BY MAJOR ACTIVITY
FOSSIL ENERGY RESEARCH AND DEVELOPMENT
(In thousands of dollars)

	FY 1983 Actual		FY 1984 Estimate		FY 1985 Request	
	B/A	B/O	B/A	B/O	B/A	B/O
COAL:						
Control Technology and Coal Preparation	27,900	22,399	26,000	25,597	32,150	33,957
Advanced Research and Technology Development	31,650	41,640	39,250	38,643	40,267	42,531
Coal Liquefaction	37,600	87,514	28,900	38,309	13,900	14,682
Combustion Systems	24,200	35,374	18,200	17,918	31,675	25,112
Fuel Cells	29,938	25,906	42,600	41,940	13,700	14,470
Heat Engines	5,112	9,410	6,500	6,399	7,650	8,080
Underground Coal Gasification	6,000	7,333	6,000	10,381	5,850	6,179
Magnetohydrodynamics	29,000	32,660	30,000	29,534	17,800	18,800
Surface Coal Gasification	38,800	52,247	36,790	36,220	15,000	15,843
Subtotal Coal	230,200	314,483	234,240	244,941	177,992	179,654
PETROLEUM:						
Advanced Process Technology ..	5,000	4,775	5,000	4,923	6,200	6,549
Enhanced Oil Recovery	6,500	7,467	9,150	9,008	13,400	14,153
Oil Shale	12,250	10,287	16,150	15,899	12,000	12,674
Subtotal Petroleum	23,750	22,529	30,300	29,830	31,600	33,376
GAS:						
Unconventional Gas Recovery ..	13,680	12,923	15,500	15,260	8,550	9,030
POLICY AND MANAGEMENT:						
Policy and Management	43,300	52,966	49,540	49,969	54,728	58,414
PRIOR YEAR OFFSETS	-20,136	...	-27,326	...	-58,839	...
APPROPRIATION TRANSFERS	-73,700	...	-42,040	...	-11,300	...
TOTAL	217,094	402,901	260,214	340,000	202,731	280,474

DEPARTMENT OF ENERGY
FY 1985 CONGRESSIONAL BUDGET REQUEST
SUMMARY OF ESTIMATES BY APPROPRIATION BY MAJOR ACTIVITY
ENERGY SUPPLY RESEARCH AND DEVELOPMENT
(In thousands of dollars)

	FY 1983 Actual		FY 1984 Estimate		FY 1985 Request	
	B/A	B/O	B/A	B/O	B/A	B/O
Liquefied Gaseous Fuels Spill Test Facility	3,500	113	3,250	3,937	2,000	4,700
Total	3,500	113	3,250	3,937	2,000	4,700

THE TECHNOLOGY DEVELOPMENT PATH

These Steps Are Defined Briefly as Follows

Basic Research:

Studies Directed Towards Development of Fundamental Scientific Knowledge Leading to the Definition of New Energy R&D Concepts;

Applied Research:

Activities to Resolve Broad Engineering and Physical Science Problems in Specific Fossil Technologies and Related Areas; However Practical Utility May Not Be Proven At This Stage;

Proof of Concept:

Development to Resolve Specific Problems to Determine the Technical and Environmental Feasibility of the Integrated Process. Data is Generated to Evaluate Critical Scale-Up Parameters, Characterize Sub-Systems, Processes, and Products, and to Permit Preliminary Economic Projections to be Made;

Process Development:

Increasingly Larger Scale Engineering Design, Construction and Operation of Energy Systems With the Objective of Reducing Technical Risks and Improving the Process Operability, Reliability, Economics, and Environmental Impact;

Commercialization

Wide Variety of Efforts to Eliminate Technical, Economic and Institutional Barriers Required for Acceptance of a New Energy Technology into the Marketplace.

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Senator FORD. Thank you very much, Mr. Vaughan. Mr. Mares.

STATEMENT OF JAN W. MARES, ASSISTANT SECRETARY FOR POLICY, SAFETY, AND ENVIRONMENT, DEPARTMENT OF ENERGY

Mr. MARES. Thank you, Mr. Chairman. I would ask that my formal statement be submitted for the record and I will try to summarize it.

Senator FORD. Your statement will be included in the record as if it were given. You may abbreviate.

Mr. MARES. Thank you, Mr. Chairman. I have been asked to address the subject of acid rain research. I would be pleased to do that. Since there are a large number of agencies within the Government involved in this program, I am not going to attempt to provide a comprehensive review of the program, but rather to present an overview of the research effort and discuss that effort in the perspective of policy and environmental assessment.

The administration believes more scientific information is needed before an appropriate decision can be made on additional emission control measures to reduce acidic deposition. The administration recognizes that acidic deposition and related effects is a very serious concern. However, we believe strongly that numerous uncertainties currently prevent the selection of a suitable approach.

Among those uncertainties include whether additional emissions control is warranted. I want to emphasize the word "additional." With the existing Clean Air Act, all precursors of acid deposition are regulated. Neither the level nor trend, in adverse effects attributable, with confidence, to acidic deposition is of sufficient magnitude to constitute an emergency situation. If we decide to address further uncertainties, the first one that we need to address is what to control, things like SO_x, NO_x, volatile organic compounds, and other pollutants. We need to know where to control them. Should we apply controls to local sources, distant sources, or nationwide?

A third uncertainty would be how much to control, recognizing that the cost of any control should be less than the benefits that we are seeking to achieve.

And, finally, how fast should there be control? Since available data indicates that the acid rain damage is not changing rapidly, the question is whether we let the existing powerplants or other sources retire in normal course or whether we try to accelerate that. All of these uncertainties are being focused on in the course of the research program, as well as at least five basic approaches that have been proposed or suggested regarding the acid rain problem. They being continuation of the current act: a phased control which would allow an acceleration of the expected long-term emission decline; administrative management, that is amending the act to improve the authorities of the EPA, which would let EPA decide when and how to use those authorities; the targeted approaches; and finally, the approaches which have been the subject of much proposed legislation, the broad area emission rollback approaches.

My purpose in discussing this has been to explain why a control decision is premature now because of the uncertainties that are involved, the range of potential approaches which may not be all inclusive to the acid rain problem, and the kinds of findings which would support alternative approaches.

Considerable scientific progress has been made in the last several years. I have listed some of these findings on pages 15 and 17 of the testimony. When we think about what the plans are for 1985 and the future, we have identified in attachment 1 an overview of the National Acid Precipitation Assessment Program for 1985. This program, which amounts to about $55.5 million, is a 100-percent increase over the program of fiscal 1984 and is focused in several areas.

About 40 percent of the effort deals with effects research, meaning what are the effects on aquatic areas, what are the effects on the land, what are the effects on materials. About 30 percent of it deals with the development of models to relate the omissions to deposition, that is models of the atmospheric change and transport processes. This is an area where the Department is putting its contribution in the $55.5 million; the largest part of the Department's contribution is in this modeling area.

Finally, monitoring of deposition. This information is a key input to both models and effects assessment and this will take about 15 percent of the requested funds.

More particularly, the effects research is going to be expanded for aquatic areas, forests, and materials. Surveys and inventories of the characteristics and conditions of lakes, streams, and forests will be expanded. These efforts will improve our understanding of the magnitudes and locations of existing damage and susceptibility to possible future damage. It will also enhance our ability to detect trends.

Development of an advanced transport-transformation model is integral to the National Acidic Precipitation Assessment Program. Such a model must rely on field data to calibrate its numerous parameters. A larger DOE initiative seeks to determine how and at what rate emitted species, such as SO_2 and NO_x, are transformed into acid species.

DOE is also cooperating closely with EPA, EPRI, and NOAA in the design of a large field experiment to determine empirically the geographic relationship between emission sources and receiving areas.

The Department has also entered into a memorandum of understanding with EPA to create an acid deposition assessment staff to produce major assessment reports in this regard. The 1985 assessment report will provide the most definitive estimates yet developed of the extent of acid deposition effects. It will also detail the limitation and uncertainties of source/receptors models developed by that time. As much as we would like it to be otherwise, the 1985 assessment report cannot tell us how effects on ecosystems might change as a result of changes in emissions, because the necessary scientific tools for doing such an analysis will not exist. Major assessments in 1987 and 1989 will give increasingly more reliable answers to this most fundamental policy problem.

In order to summarize, I would say the uncertainties over the magnitude, distribution, trends, causes, and source-receptor relationships of acidic deposition currently preclude a confident choice of a control approach to the problem.

The probability that serious and/or widespread damage could result if emissions are not further reduced appears low for the near term. The magnitude of long-term damage which occur under the current Clean Air Act is unknown.

Adverse effects have occurred and might increase in the future. This has produced a serious environmental concern. The administration believes strongly that a substantial research and analysis program, such as I describe in more detail in my statement, is needed to reduce uncertainties and assist the selection of an appropriate response to the acid rain issue.

The Federal Research and Analysis Program is organized to provide progressively detailed assessments of the cause and effect relationships and alternative control approaches, beginning in 1985.

The President's budget request for this program of $55.5 million is a 100-percent increase from the fiscal year 1984 budget.

A program for research, development, and demonstration of control methods, in parallel with the National Acid Precipitation Assessment Program, will enhance the effectiveness and/or reduce the cost of any approach selected. Mr. Vaughan has described to you in both his formal statement as well as here earlier a substantial part of that federally funded research, development, and demonstration program.

In the meantime, assistance to States for lake liming, backed by liming research, will improve water quality in sensitive, affected lakes.

The administration believes that this approach provides an appropriate balance between the concerns and the uncertainties over the acid rain issue.

That concludes my comments and I would be glad to answer any questions, Mr. Chairman.

[The prepared statement of Mr. Mares follows:]

STATEMENT OF

JAN W. MARES

ASSISTANT SECRETARY

POLICY, SAFETY AND ENVIRONMENT

U.S. DEPARTMENT OF ENERGY

Good morning Mr. Chairman and members of the Committee. I am Jan W. Mares, Assistant Secretary of Policy, Safety and Environment, U.S. Department of Energy. You have asked me to address the subject of acid rain research. I am pleased to discuss that subject with you. Since many Agencies and organizational elements are involved in the research program of the Federal Government, I will not attempt to provide a comprehensive review of the research program but rather, to present an overview of the research effort and discuss that effort in the perspective of policy and environmental assessment.

A. Administration Policy

EPA Administrator Ruckelshaus testified, on Feb 2, to the Committee on Environment and Public Works that the Administration believes more scientific information is needed before an appropriate decision can be made on additional emission control measures to reduce acidic deposition. The Administration's budget for research to obtain such information is $55.5 million in FY 1985, a 100% increase from the FY 1984 budget of $27.5 million. In addition the control technology research budget has been substantially increased, and $5 million has been designated for aid to states in mitigating effects on lakes and their fish populations.

As the Administrator emphasized, unwillingness to recommend additional sulfur oxides controls at present does not mean that the door is closed on measures to address this matter. The Administration recognizes that acid deposition and related effects is a serious concern. However, we believe strongly that numerous uncertainties currently prevent the selection of a suitable approach.

B. Uncertainties

As a first step towards putting the research program in a policy perspective, I will briefly review the uncertainties surrounding current understanding of the "acid rain" phenomenon, with emphasis on the key policy questions.

The first question is whether additional emissions control is warranted. The key word is "additional." All precursors of acid deposition -- sulfur oxides (SO_2), nitrogen oxides (NO_x) and volatile organic compounds (VOC) -- are regulated under the current Clean Air Act. Such regulation, and potential future regulations under the current Act, have reduced emissions well below precontrol levels, and will reduce emissions below current levels. It is important, therefore, to understand that "no additional control" does not mean "no control". But will future reductions resulting from current

Clean Air Act authorities be sufficient? The answer depends critically on the amount of damage attributable to acidic deposition at present and the expected trend in such damage if the current Clean Air Act was not changed, a scenario which we call the "baseline."

Neither the level nor trend in adverse effects attributable with confidence to acidic deposition is of sufficient magnitude to constitute an emergency situation. The data and theory underlying this current estimate are thin and uncertain. Lake survey data are nowhere near complete. Trend data of reasonable quality are available for only the last decade or so, and are also sparse. The cause of observed forest damage is not understood, and might be due, in some part, to acidic deposition. The uncertainties are broad enough to admit the possibilities that current damage may be confined to only a few hundred lakes in the Adirondacks Park or to many more lakes around the country, and to forests and manmade materials as well. Furthermore, the trend data are too spotty and brief to determine whether existing conditions will improve, remain constant or deteriorate in the future under a "baseline" scenario. The available information suggests that current damage is not changing rapidly, and that gives us confidence that the time needed for additional research and further development of control methods will not entail a serious risk of additional damage.

When the question of "whether" is put aside and the "how" question approached, four new uncertainties are encountered.

Uncertainty #1: What to control? Aquatic damage is caused by acidification. But several pollutants are involved in the wet and dry deposition of acids; SO_2, directly emitted SO_4, NO_x, and oxidants (caused by VOC* and NO_x emissions) all contribute. Although sulfur oxides are believed by most scientists to be the major factor, acidification of aquatic environments may continue if emission reduction is limited to SO_2 and other contributors are neglected. The complex atmospheric chemistry leading from precursor emissions to acidic deposition is not well understood.

Forest damage is hypothesized to be caused by SO_2, acid, NO_x, ozone, particulate matter (especially trace elements), natural stresses and/or combinations of those. Clearly, a strategy for preventing forest damage can't be developed before the cause(s) of that damage is identified.

Crop damage can be caused by many things, including excessive exposure to ozone, SO_2 and acid. Significant damage to crops in the field does not appear to be acid related, and excessive exposure to ozone and SO_2 is limited by ambient standards for those pollutants. However, subtle synergistic effects involving acidic deposition and other causes cannot be ruled out until ongoing research is completed.

*volatile organic compounds

The severity of the impact of air pollution on materials, relative to natural and other stresses, is not quantifiable at present. The deterioration of manmade materials and cultural artifacts appears to be related more to exposure to locally generated gases and particulates than to regional emissions or acidic precipitation. We can not, however, rule out the influence of acid rain on materials deterioration. Furthermore, the reduction of acid rain precursors themselves, especially SO_2 and directly emitted sulfates, may reduce local materials deterioration directly, separate from any possible deterioration caused by acid rain.

Two other adverse effects, sometimes associated with the "acid rain" issue, are visibility impairment (haze) and public health (sulfates/fine particulates). Both are related to emission of acid rain precursors (SO_2/sulfates), for sulfates occur as fine aerosols which both contribute to haze and can be respired deep into the lungs. But haze is also caused by natural conditions, oxidants and carbon. Scientific opinion is divided over whether or not sulfates cause any adverse health effects at current exposure levels, and over whether sulfates specifically or fine PM generally is the proper measure of risk. There is no clear evidence that either direct or indirect adverse health effects are associated with "acid rain."

Uncertainty #2: Where to control? Lakes and forests exhibiting some form of damage are found primarily in the northeast and along the Appalachian ridge. Materials decay is primarily an urban phenomenon. Visibility is valued most highly in the arid west. Acid fog has been observed on the west coast (primarily nitrates) and on Whiteface Mountain in New York (primarily sulfates). Should "acid rain" control be applied nationwide? Should such control involve the same emissions to the same degree in all regions? Answers to such questions must await a better characterization of damage severity and trends for the several types of adverse effects, and the form of deposition or air pollution involved. In addition we need to know more about how widespread the various effects really are.

Once a problem and its immediate causes are identified, the locations of emission source candidates for control must next be identified. Transport and transformation models are essential for this task. Models which estimate the relationship between regional emissions (SO_2, NO_x, VOC), their sometimes long range transport to sensitive areas (e.g. the Adirondacks) and their interaction and transformation to other chemicals (oxidants, sulfates, nitrates) are in the developmental stage. The controversies over "linearity" and long range vs local transport are indicators of the uncertainties which attend current models. But the efficiency and cost-benefit of any potential approach to additional emissions control depend critically on source-receptor relationships.

Uncertainty #3: How much control? We know that control costs rise exponentially as control stringency increases. At some point, the cost curve crosses the benefits curve, after which net benefit becomes negative. A basic principle of this Administration, as expressed in Executive Order 12291, is that public programs should always be net beneficial. We can estimate a control cost curve with reasonable accuracy at present; we cannot estimate a benefits curve. Attempts to date to estimate the magnitude and value of damage due to acidic deposition have had to rely on heroic assumptions. They are simply speculative "if--then" analyses. The data to provide substance to damage and benefit analyses is not yet available. Also, the application of damage and value estimates presupposes that the type and sources of emissions causing the damage have been identified. As I have tried to make clear in the foregoing, this is not the case at present.

Uncertainty #4: How fast to control? As I noted earlier, the available data suggest that the "acid rain problem" is not changing rapidly. We also project that a long term reduction in SO_2 emissions will occur under the current Act as old plants retire and are replaced by new ones meeting New Source Performance Standards (NSPS). That expected decline could be accelerated but such acceleration would result in increased costs to the economy and impacts on the coal market, with no assurance of commensurate benefits. However, as I have pointed out in the foregoing, the data and analytical tools for estimating trends and benefits are inadequate to draw conclusions with confidence. A number of different approaches to the acid rain issue might be supportable, depending on the results of the research program.

C. Alternative Approaches

Ther are at least five basic approaches to the "acid rain" problem which have been proposed or suggested:

- Baseline (continue the current Act)
- Phased control (accelerate the expected long term emission decline)
- Administrative management (amend the Act to improve EPA authorities, let EPA decide when and how to use those authorities)

- o Targeted control (address protection of sensitive aquatic areas, urban materials, western visibility as separate problems)

- o Rollback (mandate specific reductions of SO_2 and/or NO_x in 31-48 States by the early to mid 1990s)

Each approach has a number of sub-options; I will mention only a few of those. The descriptions below will concentrate on the key research findings which would indicate the desirability of one or another approach.

1. Baseline

The current Act requires that NSPS be promulgated for all major emission categories and that such NSPS be reviewed every four years and revised if appropriate. Current estimates of future "baseline" emissions all assume that no new NSPS or NSPS updates will occur. We call such projections "passive baseline." They represent an improbable worst case, for EPA will surely exercise its NSPS authorities in the future. An "active baseline" would assume more and tougher NSPS, but the degree and timing of such actions are inherently uncertain and difficult to estimate.

In addition to the NSPS authority, the current ACT requires that ambient air quality standards be promulgated for any air pollutant which threatens the public health or welfare, and that such standards be reviewed for adequacy every five years. Ambient standards exist for all of the acidic deposition precursors or pollutants. An "active" baseline could include revisions of those standards, if research findings were to support such revisions.

Current passive baseline estimates for SO_2 indicate fairly constant emissions through 2000 and a decline thereafter. Such estimates depend heavily on assumptions regarding economic growth, nuclear electricity generation and the retirement age of old plants. Optimistic, "active" baseline estimates indicate that an additional decline in SO_2 emissions of up to 10 million tons per year could be achieved before the year 2030. Reality will probably lie between those estimates, and will depend on advances in control technology.

Adoption of the "baseline" as the solution to the acid rain problem would be attractive if current indications of moderate damage were confirmed and trends in damage were found to be declining, static or very slowly increasing. In other words, the Clean Air Act already includes a long-term "solution" but we're not certain whether we're facing a problem which is primarily long-term.

2. Phased Approach

Various analysts have pointed out that the reason why SO_2 is not expected to respond faster to the NSPS is the long lifetimes of large coal-fired utilities. Current estimates of such lifetimes extend to 60 years and even beyond. When such estimates are combined with the fact that some existing plants not subject to NSPS came on line as late as the mid 1970s, it becomes clear that we may have to wait until after 2030 under a "baseline" strategy for the last of those less controlled plants to retire. Congressmen Madigan and Broyhill of the House of Representatives' Committee on Energy and Commerce have suggested a method of reducing that long wait while minimizing both cost and coal market impacts. The method is to require that powerplants either retire at age x or reduce emissions to level y when the "decision age" is reached. Age x and level y are analytical variables at present, but if x is less than 60 years and y is less than the 3.2 pounds SO_2 per million BTU average (in 1980) for utilities, then SO_2 would decline more rapidly than under baseline assumptions.

In essence, the Broyhill-Madigan suggestion is similar to "rollback" except that it would mandate emission reductions by utilities rather than by States and would achieve those reductions over an extended time rather than by the early to mid 1990s. Cost savings (relative to rollback) would be achieved in three ways: by delaying control for most plants (time is money), by taking advantage of the richer array of control techniques likely to be available in the future, and by allowing, for plants choosing to control rather than retire, the combination of major refurbishment with control installation (assuming the "decision age" is chosen accordingly). Coal market disruption would be reduced by phasing in controls (some of which will be switches to low sulfur coal) as demand for high sulfur coal increases (new capacity to meet rising electricity demand will often use high sulfur coal). Most plants would reach the "decision age" between 1995 and 2010. By that time, the demand for high sulfur coal will have increased substantially. In addition, new control methods will allow choices other than "scrub or switch," and that could reduce the amount of coal switching. While an opportunity cost would be imposed on the high sulfur coal mining industry, the absolute demand for high sulfur coal under the phased approach would not likely drop below current levels, so miner displacements might be avoided altogether.

The phased approach would be attractive if the rate of damage increase was found to be slow, the collective risks due to SO_2 emissions were judged sufficient to warrant additional control, but no "target loading" or achievement date was found to be supportable.

3. Targeted and Management Approaches

A "targeted" approach would address each problem/region combination separately, depending on its severity, emission species involved and prognosis. This approach is combined with the "management" approach because it would probably be most practical to provide EPA with enabling legislation (in addition to current authorities) and leave the use of such authorities to EPA.

These approaches would be attractive if the several effects usually lumped under "the acid rain problem" were found to be sufficiently different in cause, severity and location to be separated. Both effects/trends information and source-receptor models are important to such a potential conclusion. Even widely separated sensitive areas could be linked in a common control strategy if long range transport/transformation was found to dominate local and medium range transport.

4. Rollback

This approach is familiar, for it is the basis for the control schemes proposed in Congress to date. Loading targets and regional scope differ among the proposals (8-12 MTY SO_2 reduction, 31-48 states) as do financing methods (polluter pays, 1-3 mills/kwhr tax), but the generic result would be a large SO_2 emission reduction by the early-to-mid 1990s.

Rollback could become attractive if adverse effects were found to be more substantial than currently estimated and/or rapidly increasing, and if such effects were found to be widespread or linked via long range transport. Given such findings, a 31 state rollback would be more appropriate to a strictly acid deposition related strategy, while 48 state rollback would be indicated if western visibility and public health risks were shown to be serious and/or if research results indicate that western waters are at risk of acidification.

I cannot emphasize strongly enough that I am not advocating any of the approaches presented above, but rather, I am offering them as "if--then" possibilities contingent upon research and analytical results. My purpose in all of the above has been to explain why a control decision is premature now, what uncertainties are involved, the range of potential approaches (which may not be all inclusive) to the "acid rain problem" which have been suggested for consideration and which remain viable within current uncertainties, and the kinds of findings which would support alternative approaches.

D. The Research Program

Recent Findings

Considerable scientific progress has been made over the past months. This progress has taken several forms. In some cases, consensus about long-standing issues is developing. In other cases, topics not previously examined closely have been shown to be extremely complex, and adequate understanding remains elusive. In still other cases, perhaps the majority, knowledge has been advanced incrementally; although such advances may be less dramatic, they are no less important. I will list here a few recent highlights of the research program.

- In the aquatic effects area, two major studies have concluded that sulfate in Northeastern surface waters has decreased since about 1970. This is especially encouraging since the Northeast contains some of our most sensitive surface waters. At the same time, less conclusive data seems to indicate that sulfate in surface waters has increased in some other areas of the United States. Some researchers are using this information together with data on sulfur emission patterns to support the hypothesis that sulfate in surface waters roughly follows emission trends, especially in the Northeast.

- Several researchers have further examined the role that soils play in the acidification of surface waters. The thrust of some of their results is that soil constituents such as organic acids play a more complex role than previously thought. In one notable study by the Tennessee Valley Authority, it was suggested that acid deposition might have the effect of simply displacing acids from natural sources in soils, so that the pH of the surface water they studied had not been altered by deposition.

- A widespread decline in the growth of certain tree species beginning between about 1957 and 1962 has recently been detected in several areas of the eastern United States. The cause of this decline is unknown; numerous hypotheses are being formulated and tested. Preliminary analysis indicates, however, that the patterns of forest decline do not correlate with patterns of acid deposition or regional sulfur or nitrogen emissions, but the possibility that either acid deposition or gases act synergistically with other environmental factors cannot be ruled out.

- A major project sponsored by the Department of Energy, the Cross-Appalachian Tracer Experiment (CAPTEX), showed that it is possible to tag air parcels with

> nonradioactive tracers and track air movements over the distances upwards of 1000 km. This capability is an essential building block for future large experiments aimed at empirically determining how emissions from one area of the country are transported to other areas.

Despite significant recent advances in the state of science, many key issues remain unresolved. Some of these issues were discussed just last Monday when EPA Administrator Ruckelshaus, under the auspices of the National Academy of Sciences, held another in his series of symposia with leading scientists. The point to be made here is that there is little lag time between the development of scientific understanding through NAPAP projects and its dissemination to key Administration decisionmakers.

In the face of the scientific and political controversy which characterizes the acid rain issue, it is doubly important that NAPAP research adhere to the highest standard of scientific credibility; and this continues to be one of the major goals of the ITFAP. Accordingly, the ITFAP early on established a thorough peer review process under which every project is periodically reviewed for its scientific quality and productivity.

PLANS FOR FY 1985 AND THE FUTURE

An overview of the National Acid Precipitation Assessment Program for FY 1985 is provided in Attachment 1. The DOE budget request for NAPAP and control technology R&D is provided in Attachment 2. Note that control R&D is largely outside the program. A final item rounds out Federal "acid rain" related activities: $5 million for liming assistance to states, to be administered by the Department of the Interior.

The NAPAP activities are divided into nine task groups devoted to particular research and analysis areas:

- The critical effects research is conducted through TGs E(aquatics), F(terrestrial effects) and G(materials).
- Inventories and projections of the several emission species which contribute to acidic deposition are developed by TGs A (natural sources) and B (manmade sources).
- The development of models to relate emissions to deposition is done by TG C(atmospheric processes).
- Deposition monitoring (a key input to both models and effects assessments) is supervised by TG D.

- Control technology assessment is conducted by TG H, but most RD&D is under separate funding and management.

- Integration and analysis of the policy implications of all TGs is carried out by TG I.

There are literally hundreds of research and analysis tasks carried out under NAPAP. The major new initiatives proposed for FY 1985 are described in Attachment 1. I will mention a few of them as they relate to the uncertainties discussed earlier.

- Effects research will be expanded for aquatic areas, forests and materials. Inventories of the characteristics and condition of lakes, streams and forests will be expanded or initiated and ecological monitoring will be intensified. These efforts will improve our understanding of the magnitude and location of existing damage and susceptibility to possible future damage. They will also enhance our ability to detect trends. While long term trends require long term monitoring to quantify with precision, especially if such trends are slow, an intensive monitioring program can quickly identify any rapid departure from the status quo. Thus the current estimate that trends are slow (positive and/or negative) will not likely be definitively confirmed in a few years, but if that estimate is substantially wrong, then the error is likely to be detected. The system of representative lakes for intensive monitoring is thus called an "early warning" scheme.

- Development of an advanced transport-transformation model has always been integral to the NAPAP. Such a model must rely on field data to calibrate its numerous parameters. A larger DOE initiative seeks to determine how and at what rate emitted species such as SO_2 and NO_x are transformed into acid species. Such an understanding of atmospheric chemistry is critical to predicting how patterns of deposition might change as the result of future changes in emissions.

DOE is also cooperating closely with EPA, EPRI and NOAA in the design of a large field experiment to determine empirically the geographic relationship between emission sources and receiving areas. There is unanimous agreement that the technology demonstrated by DOE's CAPTEX experiment will be used in any large field experiment. When all the remaining technical questions are ironed out, there is every indication the the implementation of a large field experiment would also be a coorperative effort between several Federal agencies and EPRI.

- Research on the methods, benefits and limitations of lake liming will assist the states in the appropriate use of the $5 million in Federal assistance funds designated for that purpose.

- DOE entered into a Memorandum of Understanding in FY 1983 to create the Acid Deposition Assessment Staff to produce major NAPAP assessments. DOE provides both manpower and financial support for these major assessments, the first of which is scheduled for 1985. The 1985 Assessment will provide the most definitive estimates yet developed of the extent of acid deposition effects. It will also detail the limitations and uncertainties of source/receptor models developed by that time. As much as we would like it to be otherwise, the 1985 Assessment cannot tell us how effects on ecosystems might change as a result of changes in emissions, because the necessary scientific tools for doing such an analysis will not exist. Major assessments in 1987 and 1989 will give increasingly more reliable answers to this most fundamental policy question.

The RD&D on control methods and low emission processes, pursued separately from NAPAP by DOE, EPA and others (e.g., EPRI, TVA), will be valuable regardless of the control approach eventually selected. Under a "baseline" approach, the new and improved methods will allow NSPS to be upgraded, met at less cost or both. Under an approach which requires additional retrofit emission control, the new methods will also improve effectiveness and/or cost, and should provide some relief to the high sulfur coal industry.

E. Summary

- Uncertainties over the magnitude, distribution, trends, causes and source-receptor relationships of acidic deposition currently preclude a confident choice of approach to the problem.
- The probability that serious and/or wide-spread damage could result if emissions are not further reduced appears low for the near term. The magnitude of long-term damage which might occur under the current Clean Air Act is unknown.
- Adverse effects have occured and might increase in the future. This has produced a serious environmental concern. The Administration believes strongly that a substantial research and analysis program is needed to reduce uncertainties and assist the selection of an appropriate response to the "acid rain" issue.

- The Federal research and analysis program is organized to provide progressively detailed assessments of the cause-effect relationships and alternative control approaches, beginning in FY 1985.

- The President's budget request for this program of $55.5 million is a 100 percent increase from the FY 1984 budget.

- A program for research, development and demonstration of control methods, in parallel with NAPAP, will enhance the effectiveness and/or reduce the cost of any approach selected.

- In the meantime, assistance to States for lake liming, backed by liming research, will improve water quality in sensitive, affected lakes.

- The Administration believes that this approach provides an appropriate balance between the concerns and uncertainties over the "acid rain" issue.

That concludes my prepared comments. I will be happy to respond to your questions.

Attachment 1

NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

President's Budget Request
FY 1985
($ in thousands)

		USDA					DOI					
	EPA	CSRS	ARS	FS	NOAA	DOE	PS	GS	FW	BLM	TOTAL	%
A. Natural Sources					855						855	1.5
B. Man-made Sources	1200					750					1950	3.5
C. Atmospheric Processes	10,576				1005	5260					16,841	30.3
D. Deposition Monitoring	4357	248		146	500	977	322	1870		80	8500	15.3
E. Aquatic Effects	8022			210		150	148	445	1525		10,500	18.9
F. Terrestrial Effects	5610	1045	384	1758		120	329	486			9732	17.5
G. Effects on Materials	975						970	150			2095	3.8
H. Control Technologies	600										600	1.1
I. Assessments and Policy Analysis	3025					1400					4425	8.0
Subtotals:		1293	384	2114			1769	2951	1525	80		
TOTALS:	34,365	3791			2360	8657	6325				55,498	
(%)	(61.9)	(6.8)			(4.3)	(15.6)	(11.4)					

PROGRAM DESCRIPTION

The National Acid Precipitation Assessment Program is designed to successively improve our understanding of the causes, effects and possible solutions to the acid rain problem. The Program includes research, monitoring and assessment activities that emphasize the timely development of a progressively firmer scientific basis for decision making by the Congress, regulatory agencies, natural resource managers, private sector managers, environmental groups, and the public. The National Program consists of over 200 interrelated projects, which are funded by several Federal agencies, in nine major research categories including natural sources, man-made sources, atmospheric processes, deposition monitoring, aquatic effects, terrestrial effects, effects on materials, control technologies, and assessments and policy analysis. Hundreds of scientists in government, academia, and the private sector are involved in the National Program.

PROPOSED CHANGE

In FY 1985, the President's budget request for this comprehensive national research program is $55.5 million, or a 100% increase over the FY 1984 budget of $27.5 million. This increase in funds reflects important research priorities, and accelerates the rate at which scientific uncertainties are narrowed so that the pressing policy questions can be addressed more adequately.

RATIONALE

In addition to the ongoing base research in FY 1984, the major new initiatives proposed for FY 1985 include the following:

- Major Atmospheric Study: The Environmental Protection Agency, the Department of Energy, and the Electric Power Research Institute are cooperating in planning a large-scale, comprehensive atmospheric field study. The FY 1985 funding will be used to complete experimental designs, validate instruments, and field test sampling protocols and tracers. ($7650K)
- Wet and Dry Deposition Monitoring: The number of wet deposition monitoring stations will be increased significantly, and the dry deposition methods research and development will be accelerated. Dry deposition process studies will also be undertaken to support the establishment of future dry deposition monitoring stations. ($500K - wet; $1000K - dry)
- Liming Studies: A feasibility study on the benefits and limitations of lake liming as a possible mitigation strategy will be initiated in FY 1985. These research and demonstration projects are necessary prior to any possible field applications in order to study the range of different liming options, and their physical and biological effects on acidified aquatic systems. ($1000K)
- Ecological Monitoring Program: The ongoing long-term monitoring program will be expanded to include more intensive ecological monitoring, so that a change can be observed at a more detailed level, thereby increasing the ability to understand the processes as well as the ability to detect change. This part of the ongoing effort is needed to intensively monitor the environment to observe relationships between deposition and aquatic and terrestrial effects in the areas of the country that are believed to be sensitive to acidic inputs. ($3000K)
- Surveys of Lakes and Streams, and Forests: In FY 1985, the initial planned lake survey will be expanded to include several hundred streams, as well as fisheries in a select number of lakes. The purpose of the national lakes survey is to quantify the current water chemistry of lakes and streams, determine the status of fisheries and other biotic resources, and select regionally representative surface waters to quantify future changes in aquatic resources through a long-term monitoring system. ($2000K)

  Also in FY 1985, a national survey of forest damage and sensitivity will be initiated. In order to fill other critical gaps in forestry research, studies on soil processes and field effects will be enhanced. The data provided by these surveys will be essential to a better understanding of the existing and potential extent of the acid deposition problem. ($3000K)
- Field Exposure of Materials: The program on field exposure of materials will be expanded in FY 1985 to address the problem of multiple pollutants attacking construction materials. The study of the effects of acid deposition on materials is another important aspect of the ongoing national research program.

- Control Technologies: In FY 1985, the National Program includes funds for analyses of specific control technology issues important to acid deposition. (However, hardware development for the control of SO_2 and NO_x is funded under pre-existing programs at EPA, DOE and TVA.) In FY 1985, studies will be initiated on assessing the potential for control of directly emitted acid materials, and on technology combinations and modifications for moderate SO_2 control at a low cost. The Limestone Injection Multistage Burner (LIMB) is one promising new technology for the control of both SO_2 and NO_x, which eventually could provide more cost-effective methods of controlling acid deposition precursors. ($600K)

- Current Damages Assessment: One of the important milestones of the National Program is an assessment of the magnitude of current damages from acid deposition, and estimates of the uncertainties associated with the source/receptor relationship. This major assessment is underway and should be completed in FY 1985.

EFFECTS OF PROPOSED CHANGE

This increase in the budget of the National Program will enhance the effort to resolve the key scientific questions, such as determining long-term biological and ecological effects, and understanding the complex physical, chemical and meteorological relationship. In FY 1985, the additional resources will be used to initiate the large-scale atmospheric field study and enable a more complete understanding of the source/receptor relationship. The increased emphasis on surveys of sensitive aquatic and terrestrial resources are essential for the comprehensive damage assessment due in FY 1985, and will utlimately refine our knowledge of the cause and effect relationships. It will require a sustained and systematic effort over the coming years to significantly reduce the major uncertainties about the causes, effects, and management of acid deposition.

Attachment 2

FY 1985 DOE BUDGET REQUEST
FOR ACID RAIN RELATED ACTIVITIES

The total acid rain budget request for acid rain related activities is $66.06 M. DOE's principal efforts in acid rain are in:

- Policy and Program Assessments
- Interagency Task Force on Acid Precipitation
- Technology Research and Development

The breakdown for this funding is as follows:

Office of Energy Research/ Office of Policy, Safety and Environment (PE/ER) (Policy assessments, atmospheric sciences, research assignments, other scientific activities.........................	$ 3.25 M	$ 8.66 M
Office of Fossil Energy (FE) (Cleanup Technology/Coal Preparation/ Combustion/Interagency Task Force)...........	36.86 M	57.40 M
Total	$40.11 M	$66.06 M

DOE Interagency Task Force Funding Profile (in thousands)

Interagency Task Force Category	1984	1985
A. Natural Sources	$ 0	0
B. Man-Made Sources	260	750
C. Atmospheric Process	952	5,260
D. Deposition Monitoring	550	977
E. Aquatic Impacts	550	150
F. Terrestrial Impacts	50	120
G. Materials	0	0
H. Control Technology	0	0
I. Assessments and Policy Analysis	1,175	1,400
	$3,247	$8,657

Control Technologies Funding Profile

	1984	1985
o Cleanup Technology/Coal Preparation		
Flue Gas Cleanup	$ 8,100	$14,025
Gas Stream Cleanup	7,000	4,975
Waste Management	2,900	2,000
Coal Preparation	8,000	11,150
Subtotal	26,000	32,150
o Combustion Systems		
AFB Combustion	1,400	2,500
AFB Demo (EPRI/TVA)	—	15,000
PFB Combustion	7,500	5,000
Adv. Combustion Tech.	1,700	2,000
Subtotal	10,600	24,500
o Acid Rain Task Force (Man-Made Sources Work Group)	260	750
TOTAL	$36,860	$57,400

Senator FORD. Thank you very much, Mr. Mares.

Before I get into any questions, I would like to read a statement and include some items in the record as it relates to my statement. Actually the Clean Air Act has had a major impact on SO_2 emissions. One, the SO_2 emission standards have been continuously tightened over the last decade. Second, the act requires industries causing air quality problems to reduce their SO_2 emissions until the standards could be met.

Third, the act requires all powerplants, the major source of SO_2, built after 1978 to adopt scrubbers or the equivalent to reduce SO_2 emissions.

Kentucky has been in the forefront, in my opinion and that of others, in all of these areas. SO_2 emissions and air quality levels have diminished significantly in Kentucky and the State is installing scrubbers at a rapid pace. In 1982, no other State had as many FGD units or as much FGD capacity as Kentucky had operating and under construction.

In fact, many States have no scrubbers at all, including all of New England. New York with about the same SO_2 emission as Kentucky has one small FGD unit. The entire country of Canada does not have a single scrubber and none are planned, according to my information.

This then forms the background against which to measure Kentucky's efforts in controlling utility SO_2 emissions through FGD. Kentucky's electricity generation has traditionally been largely coal-based and this trend is expected to continue into the future.

Another trend has been in the increasing adoption of flue gas desulfurization FGD devices for the control of SO_2 emissions at the States utilities. In fact, Kentucky has become a leader in FGD with 20 units representing 8,417 MW either operating or under construction. This is up from just 324 MW in 1976. All of Kentucky's planned generating plants—5,306 MW—will have FGD. The growth in FGD has been accompanied by a major reduction in SO_2 emissions. Emissions decreased by a third in Kentucky between 1976 and 1982. The cost of this program has been significant also.

The scrubbers operating in 1983 in Kentucky cost a total of $598,400,000 to install; the units under construction will cost an additional $1,171,700,000, all in 1983 dollars. The total capital cost of these units, $2,251,400,000, represents about $2,400 for each family of four in Kentucky. Acid rain control legislation which could require retrofitting existing powerplants with FCD would increase these costs substantially.

While reducing SO_2 emissions. Scrubbers reduce their own set of environmental problems. Most of these seem to be manageable with proper design and operation.

The greatest disadvantage of FGD is the sludge waste that is produced. All the SO_2 removed through flue gas must leave the process in a waste stream usually a sludge that must be disposed of. This is most important from a land use aspect as large volumes of waste are generated.

Over their 40-year expected life—this is amazing to me, but nevertheless this is the best information I have—over their 40-year expected life, the existing and planned FGD units in Kentucky will generate approximately 170,000 acre fields of waste. We have already spent in Kentucky in the existing units $598.4 million. Under construction, the cost will be approximately $485 million, and the plants that are planned will exceed $1.1 billion. So we are looking at $2 billion in construction and yet we are not sure that all of these are going to be as helpful and that they will not create additional environmental problems.

Now, let me give you a schedule for Kentucky that I think is significant as it relates to any cutoff date. In 1976, we were responsible for 1,543,299 tons of SO_2. In 1978 we went up 2,000 tons over 1976. But in 1980 we reduced it to 1,109,496—approximately a 400,000-ton reduction. In 1982 we dropped even significantly more to 1,039,000 tons.

If we get back to a 1980 base year, you will find that Kentucky and maybe some other States would not be receiving credit where it has reduced its emissions by over a half-million tons a year.

I think the point I am trying to get at here is that we do not penalize the States that have made an effort, where we have. I emphasize Canada, because they seem to be doing more talking than the United States as it relates to acid rain. I would hope that we would look at our international problems as well as our national problems.

Mr. Vaughan, I will ask you a question or two and Mr. Mares a question or two. I understand your reluctance as you said, Mr. Vaughan, being the new boy on the block and under those circumstances, I will have some questions that I will give you in writing and ask that you acknowledge those as soon as possible. It might be one of our better ways in order to help you and that way maybe you will not have to take so long in the hearing today.

On page 3, Mr. Vaughan, of your statement you said that the Department's emphasis continues to be maintained on keeping budgets at the minimum level required to ensure the continuation of viable, productive core R&D programs. This sounds like a minimum life support philosophy for R&D programs, as I read between the lines.

What does it mean that you are funding at the minimum rate necessary to continue core programs?

Mr. VAUGHAN. I think what we mean there, Mr. Chairman, is that we do have to be quite concerned about Federal spending in this country. What we have tried to do is to maintain the efforts on a broad front, but try to leverage those dollars we spend in the public sector by cooperative work with the private sector. We are trying to interest the private sector, and I am heartened in conversations I have had in the short time I have had these responsibilities in cost sharing and getting more bang for the Federal dollar.

At the same time what I meant by those words is we are trying to be mindful of not allowing any viable option to go, to die on the vine.

Senator FORD. Let me ask you this question, Mr. Vaughan. We have a military emphasis in this country today. Many of us do not object to a strong defense posture, but how is our energy that would be needed by the military, how would it stack up over a protracted period of time if we find ourselves in the process of a military encounter in a conventional manner, in the Straits of Hormuz, beginning to curtail our energy source, how will industry and the military afford that cutoff?

Mr. VAUGHAN. The answer to that question, Mr. Chairman, relates really to energy vulnerability and emergency response. These are areas that essentially are oil matters and the strategic petroleum reserve is one of the prime responses that this administration has crafted to deal with that problem.

Fossil research and development programs are really much more long-term and they deal with this vulnerability problem in the sense of reducing our long-term dependence on such vulnerable sources of fuel. This is what I meant in my statement when I said we do not have that balanced mix of energy supply in this country yet. We hope, of course, it is the R&D effort that will allow us to achieve that.

Coal makes a perfect example. We in this country are the Saudi Arabia of the world in coal. Yet, we have many problems with its use. We simply must solve those problems. But it would not be candid for me to promise you solutions overnight and the R&D efforts in fossil will not solve in the short-term a cutoff from the Straits of Hormuz. Ten years from now it will have much more impact by reducing that vulnerability.

Senator FORD. With the minimum levels, that is going to extend the life on the possible security of new sources of energy, would it not, rather than trying to accelerate it? As I see it, you are just barely keeping research and development alive.

Mr. VAUGHAN. I think we are moving much more rapidly this year as opposed to the past, Mr. Chairman.

Senator FORD. What do you think next year will bring under your administration as it relates to R&D and coal, do you think you will double it next year or do you think you will go back to the same philosophy of previous years?

Mr. VAUGHAN. I do not expect us to go on the stop-start pattern that we have experienced the past several years. I would expect us to remain at current or increased levels in the future, assuming that the country can afford it.

There is always that budget trade that must be made and made at higher levels than I, or for that matter, higher levels than the Secretary himself. But I would expect that we anticipate a level effort for some time into the future.

Senator FORD. You indicate in your testimony on page 16 as it relates to MHD, your testimony indicates that if industry does not come up with 50 percent, then you propose to use the Federal funds to terminate the programs in Butte, MT, and Tullahoma, TN. Is that correct?

Mr. VAUGHAN. I think that is a too rigid characterization of where we are, Senator. We have a conference with the major players in MHD tomorrow to try to come up with a joint method with the private sector for producing a proof of concept approach to MHD.

We have proposed to enter those negotiations at the levels that you talk about, but we in no way intend to be so rigid as to say if we do not get 50 percent participation, that is the end of it. We are entering those negotiations as any negotiator with a position, but with a spirit of negotiation and a willingness to compromise if that looks necessary.

Senator FORD. Let me ask you this question, have you given up on coal liquefaction?

Mr. VAUGHAN. No, sir.

Senator FORD. You say in your statement that it is generally agreed that any significant use of coal liquefaction will probably not occur before the turn of the century and you indicate in that statement that, at least what I think, that you will focus on longer range laboratory scale projects.

Mr. VAUGHAN. The purpose of those projects, Senator, is to make sure that we adhere to that schedule. What I was trying to say in that testimony is that is our projection of when liquefaction is likely to come into significant play. However, we must continue research efforts to make sure that occurs. So we are not abandoning that program.

Senator FORD. How much of your fossil budget is devoted to the development of substitutes for liquid fuels, especially those petroleum fuels used for transportation which cannot readily be replaced by solid or gaseous fuels? Are not liquid fuels what the oil crisis is all about?

Mr. VAUGHAN. Yes, Mr. Chairman, that is essentially what the oil crisis is about. I will be glad to supply for the record the detailed breakdown of the dollar amounts devoted to that subject. We are very interested in finding ways to make coal a substitute for liquid and gaseous fuels and I am encouraged by some of the results I see coming out of R&D efforts and we intend to continue those efforts.

[The information follows:]

LIQUID FUELS RELATED TO THE TRANSPORATION SECTOR

The Fossil Energy FY 1985 budget request includes $51,725,000 for programs devoted to the development of substitutes for liquid fuels, especially those petroleum fuels used for transportation.

The programs and amounts included in the FY 1985 budget request related to the liquids category are as follows:

AR&TD liquefaction processes	$6,225,000
Coal liquefaction	13,900,000
Oil shale	12,000,000
Advanced process technology	6,200,000
Enhanced oil recovery	13,400,000
Total	$51,725,000

Senator FORD. Let me bounce to another one. I have got several areas. Given the priority that President Reagan apparently attaches to addressing the acid rain problem with adequate research before committing to any acid rain control strategy and I am absolutely in agreement with that, but how then do you justify the 22-percent cut in budget for fossil energy research and development?

Mr. VAUGHAN. First, Mr. Chairman, not all of fossil energy development is related to acid rain. Some $57 million of our budget proposal for fiscal 1985 is specifically aimed at acid rain. Also, let me point out that a number of the activities that we are involved in, while not justified and specifically aimed at acid rain measures will, if successful, have benefits in this area.

For example, any technique that improves the efficiency of burning coal means that less coal consumption is required for a given amount of energy output and that certainly would help the problem. Any work in fluidized bed, for example, while not done specifically for acid rain is driven by environmental concerns as well as efficiency concerns.

So, we have $57 million specifically identified as acid rain research, and there are additional benefits in other parts of the program. I would be glad to supply a list of these overlapping areas for the record, if you are interested, sir.

[The information follows:]

ACID RAIN RELATED RESEARCH

The attached tables provide acid rain related research in the FY 1985 budget and show the increase/decrease over FY 1984.

TABLE I

	FY 1983	FY 1984	FY 1985
Control Technology and Coal Preparation			
Flue Gas Cleanup	7,000	8,100	14,025
Gas Stream Cleanup	10,000	7,000	4,975
Waste Management	2,900	2,900	2,000
Coal Preparation	8,000	8,000	11,150
Subtotal	27,900	26,000	32,150
AR&TD			
Environmental Activities	300	260	750
Acid Rain Task Force			
Subtotal	300	260	750
Combustion Systems			
AFB Combustion	4,890	1,400	2,500
Paducah, KY AFB (TVA)			15,000
PFB Combustion	12,542	7,500	5,000
Adv. Combustion Tec.	3,000	1,700	2,000
Subtotal	20,432	10,600	24,500
TOTAL	48,632	36,860	57,400

TABLE II
POTENTIAL PERFORMANCE OF ACID RAIN CONTROL TECHNOLOGIES

TECHNOLOGY	EMISSIONS REDUCTION (%)		INCREMENTAL COST	$/TON SO_2	MATURITY
	SO_x	NO_x	(MILLS/Kwhr)		
PRECOMBUSTION					
Conventional Physical Coal Cleaning	33-50	NEG.	2-5	250-720	AVAILABLE
Advanced Physical Coal Cleaning	60-65	NEG.	4-7	270-450	COMMERCIAL LATE 80s
Physical and Chemical Coal Cleaning	90-94	NEG.	13-20	600-950	COMMERCIAL EARLY 90s
COMBUSTION					
Limestone Injected Modified Burner (LIMB)[1]	30-60	40-50	1-9	300-500	COMMERCIAL EARLY 90s
Atmospheric Fluidized Bed Combustion Retrofit	90-95	50-75	12	520-560	COMMERCIAL EARLY 90s
Pressurized Fluidized Bed Combustion Retrofit	90-98	75-85	10[2]	420-460	COMMERCIAL MID 90s
POST COMBUSTION					
Limestone Scrubber	90-95	NEG.	13-20	600-950	AVAILABLE
Dry Scrubber	70	NEG.	10-12	780-1080	AVAILABLE
Advanced SO_x/NO_x Cleanup Devices	90-95	90-95	6-10	270-610	COMMERCIAL EARLY 90s

[1] EPA FUNDED AND EPA ESTIMATES FOR $/TON SO_2.

[2] DOES NOT INCLUDE THE BENEFITS OF LOWER COST ADDITIONAL CAPACITY.

Senator FORD. There was a recent article in Automotive News. In that article it states that the White House recently set up a broad based Cabinet group to study regulatory barriers in using methanol as an automotive fuel. This would generate action within the EPA, the Treasury Department and others. Are you familiar with what the White House Cabinet group is doing, what actions have occurred, as you understand it, that those agencies regard methanol and is not the methanol label today made from natural gas? Do you see any commercial qualities and that sort of thing?

Mr. VAUGHAN. I am not intimately familiar, Mr. Ford, with the particular task force. I am aware of it. And the Department is represented on it. With respect to methanol, yes, it can be made from natural gas, but our prime emphasis is trying to make methanol from coal. We have several projects involved with the production of methanol from coal.

There are two basic approaches one can take to using methanol. One is as a fuel itself. Another approach that we are also pursuing is to convert that methanol into a raw material and use it for the full slate of gasoline, fuel oil and diesel products that you are accustomed to getting from your service station today.

Just the week before last, in fact, I added some money to an effort that we are engaged in overseas with the Germans to expand the look at methanol and particularly its use in making a full range of petroleum products. There are two ways you can approach this, as a fuel itself, in which case you will have to redesign engines and a distribution system for the fuel, or as a raw material for standard petroleum fuels. There you can phase it in with existing distribution systems and use existing combustion equipment. We are proceeding on both lines.

Senator FORD. Mr. Vaughan, I have just one more question and maybe your answer might create another one in my mind, but the rest of them I will submit to you in writing.

Mr. VAUGHAN. Thank you.

Senator FORD. In your statement on the first page you asserted that your budget request is consistent with the strategy adopted in the 1983 national energy policy plan of having "a balanced and mixed energy resource system." The testimony of the gas research institute who will testify today shows that gas related research receives $83.7 million and $1,319 million is spent on electric related, mainly nuclear research. Do you think your budget is balanced between gas and nuclear?

Mr. VAUGHAN. Yes, I think it is balanced, Mr. Chairman, when you consider the history of nuclear power and its inherent nexus to Government activity. I think that there is no way as a country that we can or should break that nexus.

When I discussed a balance and mixed program, in my opening remarks, Mr. Chairman, I felt that was a goal we had not quite achieved. We should be more reliant on abundant fuels that we have here at home and less reliant on things we have to import from outside, and we have not achieved that goal.

And, it is in that sense that this push in the program is an attempt to achieve a balanced and a mixed program. There will always be some areas of disagreement within the family of those that are interested in energy matters as to matters of degree, and I think that is healthy. That is what the hearing process is about. I do not think that we are at a major difference here with the gas industry, or for that matter any other industry that is interested in fossil fuel.

Senator FORD. I will say to you, Mr. Vaughan, your statement on page 4 indicates that $54.73 million of your request goes to policy and management. That is more than you have devoted to research and petroleum and gas combined. I think it is a little out of balance.

Senator DOMENICI [presiding]. Thank you for presiding. Thank you, Mr. Ford. Could I indicate to you my appreciation for your starting.

Senator FORD. I was very nervous about it.

Senator DOMENICI. Last week I started without you.

Senator FORD. Well, I expected that, but I did not expect to start without you though.

Senator DOMENICI. I was worried about it. But everything went smoothly then and I understand you did very well without me. That means everything is going nicely today.

Does our new member desire to ask any questions today? We are glad to have you onboard.

Senator LEVIN. Thank you very much.

Just a few questions, if I could, and I will submit most of mine for the record as well. Apparently the reduction in the budget from last year's figures represent a decision that some of the research and feasibility pilot plants should be built by private industry rather than by us. Is that basically the explanation for the reduction in the fossil program budget from $234 million to $177 million?

Mr. VAUGHAN. There are some of our projects, Senator, that we feel are at the stage that they are ready for industrial commercialization. There are other projects that we feel are much further back in the process where R&D effort is appropriate and we believe we have funded those appropriately.

Senator LEVIN. What is the reason for the reduction from 234 million to 177 million in the coal program?

Mr. VAUGHAN. The primary reason, Mr. Chairman, is the completion of a number of large scale process development units and pilot scale projects in the area of coal liquefaction, fuel cells, and surface coal gasification that we believe are available now for further development by the private sector. That is the primary reason.

Senator LEVIN. Does this represent any philosophical decision or is this just a fact of life that these plants are now built?

Mr. VAUGHAN. It is the latter, Senator. In our judgment, we have reached the proof of concept point with these projects. It is our view based on a pragmatic review of the status of those projects and the technological progress. It is not driven by philosophy at all.

Senator LEVIN. Is it driven by the budget restraint or budget crunch?

Mr. VAUGHAN. I think the entire budget of the Federal Government certainly has some concerns with the need to restrain Federal spending and this, like any other component of the Federal budget, has some of that flavor. It is one of the balance factors that was involved.

Senator LEVIN. I am sure of that. I would agree with you that we have seen much restraint in this budget. Putting that aside, some programs are funded doubly, some are increased, some are reduced, and my question—this is a 20-percent reduction in this program, and I want to know whether that is a result of any budget restraint or is that the end result that these plants are now built?

Mr. VAUGHAN. Let me try to answer the question this way, Senator. We believe the specific plants that I mentioned are ready to be put into commercial operation if private industry is interested. In other words, we believe the R&D has been completed. However, while it is true that this budget is still somewhat less than the Congress appropriated last year, this budget request for fossil energy R&D is over twice what the administration requested a year ago.

As I said in my opening remarks earlier in this hearing, we are approaching the Congress this year with the fossil energy budget, Senator, in a spirit of trying to recognize what the Congress has been telling us for the last several years, and that is they do not agree with the level. We have tried to meet you much more than halfway.

There is still some gap and I think that gap is partly driven by the need for fiscal restraint, but the days of total disagreement and rejection of the message from Congress are over.

Senator LEVIN. At least for the year.

Mr. VAUGHAN. I would expect, and I answered Senator Ford earlier, sir, that I expect it to be over as far as this administration is concerned.

Senator LEVIN. I would agree with that perhaps for a different reason.

Mr. VAUGHAN. We expect to be back next year, Senator.

Senator DOMENICI. Do not get carried away, Senator, you are running too.

Senator LEVIN. I did not explain what I meant by that. Everybody reads into it what he wants to. I am glad that the idea at least dawned on some of the members.

The last question that I have is as to your request to the OMB or to the administration this year in coal, can you give us that figure, how much did you request before it was pared down by them to 177?

Mr. VAUGHAN. To my recollection, Senator, and I was not personally in this job at the time this budget was put together, but the information I have is that on this year's budget the OMB did not cut down on their request for coal.

Senator LEVIN. Thank you. Thank you, Mr. Chairman.

Senator DOMENICI. You are most welcome, Senator.

I have four questions, three to you, Secretary Vaughan, and one to you Secretary Mares. I will let you answer them, I will give them to you and you can answer them in the next week to 10 days. I have no further questions. I thank you very much for appearing.

We are going to take the public witnesses now.

I want to say to both secretaries, I personally apologize to you for not being here. I guess you know what I am involved in and I am trying to get some kind of budget put together.

Senator FORD. Mr. Chairman, I do have about a dozen questions for Secretary Mares and I will submit those to you and you can get them back in a timely manner.

Senator DOMENICI. What do you think is timely?

Senator FORD. A week to 10 days.

Mr. VAUGHAN. That is fine.

Senator DOMENICI. Did you have any further questions, Senator?

Senator LEVIN. For the record.

Senator DOMENICI. The Senator has some also. We will have these for you now and when will yours be ready, Senator?

Senator LEVIN. Perhaps in 24 hours we can finish them.

Senator DOMENICI. He will get you his within a day. Thank you very much.

We will have our public witness panel. Frank C. Schora, president of HYCRUDE, Chicago; George Lawrence, president, American Gas Association; Howard Philipp, director, research and development, Niagara Mohawk Power Corp.; David O. Webb, senior vice president, policy and regulatory affairs, Gas Research Institute; Bernard S. Lee, president, Institute of Gas Technology.

I think that the staff at the request of the chairman has suggested to you some constraint on the use of your time, since we do want to hear from each of you and have some time for questions. Let's proceed with the witnesses, the president of HYCRUDE, Chicago, IL, Frank Schora, first, and then we will take Mr. Lawrence, Mr. Philipp, Mr. Webb, and Mr. Lee.

Let's proceed.

STATEMENT OF FRANK C. SCHORA, PRESIDENT, HYCRUDE CORP.

Mr. SCHORA. Thank you, Mr. Chairman. I am submitting for the record a longer form of my brief testimony today.

Mr. Chairman and members of the subcommittee, my name is Frank Schora. I am president of HYCRUDE Corp. formed in 1980 specifically to further research and development for production of synthetic crude oil from eastern U.S. oil shales. We see eastern shales as a major indigenous source of oil that will help supply future U.S. needs.

The strengthening of OPEC a decade ago resulted in a spurt of energy-related investigations ranging from conservation studies to research on alternate energy sources.

One such alternate identified was the Devonian oil shales located in the Eastern United States. Resource assessment studies carried out by the Institute of Gas Technology, State geological surveys and universities indicate that eastern oil shale is a major U.S. resource.

The States of Alabama, Indiana, Kentucky, Michigan, Ohio, and Tennessee contain shale deposits sufficiently rich and accessible to enable support of significant oil production for long periods.

The development of eastern oil shale as a supply of domestic liquid fuel is desirable for many reasons. The location of this resource in the central United States will assure a reliable and secure supply of high quality crude oil which is in close proximity to refineries and markets. It is in an area which has a well established socioeconomic infrastructure and available process water.

In spite of this opportunity for reduction of oil imports, development of eastern oil shale as an economically competitive source of oil is at a crossroads. The continuation of research programs and the initiation of new programs by the private sector is essentially at a standstill because of the drop in world oil prices, uncertainties in future pricing, and the temporary glut which is partially the result of depressed economies in the free world.

The development of economically viable and environmentally acceptable oil shale retorting processes for eastern shale requires a continuous effort if such processes are to be ready when they are needed in the future. We believe there is no time to be wasted in undertaking such a development, especially when there is no rational basis on which we can project the time when such processes will be needed either on a national security basis or when they will become economically justified relative to importation of oil.

I believe interruption of research and development programs for alternate energy sources such as eastern oil shale is not in the Nation's best interest. In this case, a consistent Government program is needed to foster the continuous development of the eastern oil shale data base. The program should address resource assessment, fundamental and advanced research projects and environmental and socioeconomic studies. The program should be designed to develop the technology so that the resource and the technology to utilize that resource will be in place when needed.

We at HYCRUDE will continue our effort to reestablish additional support from the private sector.

For fiscal year 1985 the allocation of $1 million to States which have commercially promising eastern oil shale deposits would provide sufficient funding to further resource characterization studies.

A funding level of $2 million we believe is necessary to support fundamental research efforts designed to significantly improve and/or modify existing eastern shale retorting processes and to investigate new, yet to be proven, technology.

Over $17 million has been spent to date by the private sector on research and development of moving-bed hydroretorting of eastern oil shale.

HYCRUDE Corp. recommends within this 2 million that 500,000 be used to continue fundamental research activities to further improve oil shale utilization and oil yield in moving-bed hydroretorting. At present we can obtain yields twice those achievable with the conventional thermal processes. Although western type thermal retort processes will produce some oil from eastern shale, it will give poorer resource utilization and economics. Technology such as retorting in the presence of hydrogen is needed to unlock the oil from eastern shale.

We also recommend one-half million be used for investigation of a countercurrent baffled fluidized bed to retort oil shale fines which must currently be discarded and $1 million for fundamental research associated with shale benefication and eastern shale chemistry.

An advanced research program of $4 million should be directed toward broadening the data base of the technologies which have yielded enhanced oil recovery from eastern oil shale, focusing specifically on moving-bed hydroretorting and other new technologies under development specifically for eastern shales.

HYCRUDE Corp. recommends $1.85 million to be allocated to advanced moving-bed hydroretorting research projects which would build upon the results of research efforts funded by the private sector. Much equipment for such a program is in place and available.

We also recommend $1 million be allocated to investigate the gasification of oil shale fines and shale residue utilizing an existing agglomerating fluid-bed gasifier and that $400,000 be allocated to investigate benefication of eastern oil shale as a process step prior to retorting.

An allocation of $2 million in fiscal year 1985 is recommended to enable development of preliminary environmental and socioeconomic data to keep pace with those other areas of development.

Thank you for the opportunity to testify here today. I would certainly be happy to answer any questions.

[The prepared statement of Mr. Schora follows:]

Statement by Frank C. Schora, President
HYCRUDE Corporation
Before the Senate Committee on Energy and Natural Resources
Subcommittee on Energy Research and Development
Hearings on Department of Energy Budget Authorization for FY 1985
March 12, 1984

Mr. Chairman and Members of the Subcommittee:

My name is Frank C. Schora. I am president of HYCRUDE Corporation, which was formed in 1980 specifically to further research and development efforts for production of synthetic crude oil from Eastern U.S. oil shales. We see these shales as a major indigenous source of oil to help supply future U.S. needs.

The strengthening of OPEC a decade ago resulted in a spurt of energy-related investigations ranging from conservation studies to research on alternate energy sources.

One such alternate energy resource identified at that time was the Devonian oil shale located in the Eastern United States. Resource assessment studies carried out by the Institute of Gas Technology, individual state geological surveys, and universities indicate that Eastern U.S. oil shale is an extensive resource.

The states of Alabama, Indiana, Kentucky, Michigan, Ohio, and Tennessee contain Devonian oil shale deposits which are sufficiently rich and accessible to enable support of significant oil production for long periods.

The development of Eastern oil shale as a supply of domestic synthetic liquid fuel is desirable for many reasons. The location of this resource in the central U.S. will assure a reliable and secure supply of high quality domestic crude oil which is in close proximity to oil refineries and markets. The resource location is in an area which has a well established socioeconomic infrastructure and available process water.

In spite of the opportunity for the reduction of oil imports which development of Eastern oil shale poses, the development of Eastern oil shale as an economically competitive source of synthetic crude oil is at a crossroads. The continuation of research programs and the initiation of new research programs by the private sector is essentially at a standstill because of the drop in world oil prices, uncertainties in their future pricing, and the temporary glut which is partially the result of depressed economies in the free world. However, the development of economically viable and environmentally acceptable oil shale retorting processes requires a continuous effort if such processes are to be ready when they are needed in the future. We believe there is no slack that can be allowed in such a development, especially when there is no rational basis on which we can project the time when such processes will be needed either on a national security basis or when they will become more economically justifiable than continued importing of oil.

Interruption of research programs for alternate energy sources such as Eastern oil shale is not in the Nation's best interest. In this case, a consistent government program is needed to foster the continuous development of the Eastern oil shale data base. The program should address the key areas which will develop the data base on Eastern oil shale. These areas are: resource assessment, fundamental and advanced research projects, and environmental and socioeconomic studies.

For FY '85 the allocation of $1.0 million to states which have commercially promising Eastern oil shale deposits would provide sufficient funding to further resource characterization studies which would provide a better understanding of the geology and geochemistry of Eastern oil shale. The amount of resource characterization work which has been performed on Eastern oil shale varies from state to state. The funding level recommended would provide for the continuation of studies which assess the richness of the oil shale resource and the feasibility of commercial development.

The inclusion of fundamental research projects in the program will ensure the continued entry of possible new process concepts designed specifically for full utilization of Eastern oil shales. Because Eastern oil shales do not respond as favorably to conventional retorting processes as Western shales, a fundamental research program is necessary to continue the development of technologies which improve the economics and efficiency of synfuels recovery from Eastern oil shales. Such a program will provide data in a form that can be readily utilized by process developers in future design efforts.

A funding level of $2.0 million in FY '85 is necessary to support fundamental research efforts designed to significantly improve and/or modify existing Eastern shale retorting processes and to investigate new, yet to be proven technology.

Over $17 million has been spent to date by the private sector on research and development of moving-bed hydroretorting of Eastern U.S. oil shale. HYCRUDE Corporation recommends $0.50 million to continue fundamental research activities to further improve oil shale utilization and oil yield in moving-bed hydroretorting using existing equipment. For example, modifications to the retort and the process operating conditions would enable utilization of most of the fines generated during shale crushing thereby improving resource utilization. Also, development of a technique to control the oil droplet size in the retort would prevent condensation of the oil vapor on incoming raw shale and its subsequent revaporization and cracking which reduces oil yield.

HYCRUDE Corporation also recommends $0.50 million for the investigation of a countercurrent baffled fluidized bed to retort oil shale fines which would increase the utilization of shale fines which must currently be discarded.

The advanced research program should be directed toward broadening the data base of the technologies which have shown enhanced oil recovery from Eastern oil shale. The advanced research program should focus on moving-bed hydroretorting and other new technologies developed specifically for Eastern oil shale. These processes have relatively near-term (within the next decade) prospects for commercialization. An allocation of $4.0 million in FY '85 will allow for continuation of advanced research on Eastern shale retorting technologies.

HYCRUDE Corporation recommends $1.85 million be allocated to moving-bed hydroretorting advanced research projects which would build upon the results of research efforts funded by the private sector. These research activities would concentrate on improving the economics of the process by reducing the consumption of hydrogen and ensuring that the most efficient shale mining, crushing, and auxiliary processing systems have been applied to oil shale retorting. Experimental work would also be performed in existing equipment to widen the Eastern shale data base and to provide analytical data necessary for environmental studies. Also, it is recommended that $1.00 million be allocated to investigate the gasification of oil shale fines and residue utilizing an existing ash agglomerating fluid bed reactor, and that $0.40 million be allocated to investigate the economics of beneficiation (enrichment) of Eastern oil shale.

Because it is important to ensure that the knowledge of effects of environmental and socioeconomic impacts keeps pace with the growing knowledge of resources and processing methods during the development of an Eastern oil shale data base, an environmental and socioeconomic study program is recommended. Since the environmental and socioeconomic issues are site-specific, they are a major concern of state and local governments. Except for instances in which research is conducted on a specific process, it is advised that funds allocated to perform environmental and socioeconomic studies be allocated to the states which contain commercially promising Eastern oil shale deposits.

An allocation of $2.0 million in FY '85 should enable preliminary environmental and socioeconomic data to keep pace with other areas of development. From a process standpoint, HYCRUDE Corporation recommends $0.40 million to investigate the environmental impacts of moving bed hydroretorting.

Thank you for this opportunity to present my views to you today. I will be happy to answer any questions you may have.

Eastern Oil Shale

Research and Development

Recommendations FY '85

PROGRAM FACT SHEET

RESOURCE CHARACTERIZATION

Resource characterization work performed to date has shown that Eastern U.S. oil shale is a major energy resource. Although it has been shown that the states of Alabama, Indiana, Kentucky, Michigan, Ohio, and Tennessee contain commercially promising oil shale deposits, the level of understanding of the geology of Eastern U.S. oil shale is below that which has been attained in the case of other major domestic energy resources.

Further resource characterization is necessary to provide a better understanding of the geology and geochemistry of the resource. This will help to identify areas best suited for commercial development and will also help to establish a baseline for environmental studies. This work can be accomplished at a comparatively modest level of funding because of the volume of basic geological data which can be used as a starting point.

Area-wide maps detailing resource composition and richness as well as surveys to determine potential by-product metals will aid in energy resource evaluation and mine planning.

Correlations of the oil yield from various processes with oil shale geochemistry and modeling of the distribution of organic materials, minerals, and fossils would simplify the evaluation of the commercial potential of oil shales in a given area.

This knowledge would help state and local governments to pre-evaluate the impact of commercial-scale oil shale development in their areas. Resource characterization work is therefore best performed by individual state agencies.

HYCRUDE Corporation recommends that $1.00 MM in FY '85 be allocated to concerned states for resource characterization work.

FUNDAMENTAL RESEARCH

Improvement of Yield in Moving-Bed Hydroretorting

Moving-bed retorting of oil shale in a hydrogen-rich atmosphere at elevated pressure (hydroretorting) has been proven to result in enhanced oil yields for Eastern shale retorting which are up to twice the oil yields obtainable utilizing conventional thermal retorting technologies. Fundamental research in two areas could result in improvements in oil shale utilization and oil yield.

Currently, 10% to 20% of the raw shale must be discarded without processing of any sort because during the shale feed preparation (crushing and screening) a portion of the shale becomes too fine to be retorted in a moving bed under current operating parameters. In order to avoid wasting this portion of the resource, fundamental research work should be performed to modify the process operating conditions and/or reactor mechanical configuration to broaden the capacity of moving-bed hydroretorting to enable processing of fines.

Oil refluxing (condensation of oil vapor on incoming raw shale and its subsequent re-vaporization) reduces the efficiency of moving-bed countercurrent oil shale retorting processes because a significant portion of the oil reacts with hydrogen to form hydrocarbon gases when the oil re-vaporizes. The investigation of mist formation systems could result in control of the oil droplet size which would help to minimize refluxing, thereby improving the oil yield and process efficiency of countercurrent moving-bed hydroretorting systems. Development in this area could also be of significant assistance to conventional thermal processes.

> HYCRUDE Corporation recommends $0.50 million in FY '85 to research methods to improve the oil shale utilization and oil yield in moving-bed hydroretorting.

Process Chemistry

Research projects which investigate both the chemistry of specific processes and general mechanisms of retorting chemical reactions are necessary. Specific areas in which further research is warranted include Eastern oil shale beneficiation process chemistry studies. Oil shale beneficiation, or concentration of the organic content of an oil shale, results in a greatly enriched oil shale feedstock which significantly reduces material handling capital and operating costs.

Existing thermal retorting processes have more complete energy recovery when spent shale is burned. However, Eastern oil shale has a higher sulfur content than Western oil shale. Therefore, another area which should be investigated is the direct combustion of Eastern shale (raw or spent). Another process chemistry study which would help to provide a better understanding of the mechanism of retorting chemical reactions is the identification of the primary and intermediate reaction products of Eastern oil shale. Furthermore, the investigation of a variety of retorting atmospheres such as steam, methane, carbon monoxide, etc., should be investigated to optimize operating conditions for achieving possible enhanced oil recovery.

HYCRUDE Corporation recommends $1.00 million in FY '85 to research Eastern oil shale retorting process chemistry.

Novel Methods for Fines Processing

Present technologies for processing shale fines do not incorporate efficient countercurrent heat recovery from the processed shale because oil refluxing causes the fines to plug up the retort. The use of a countercurrent baffled fluidized bed that incorporates oil droplet size control can retort shale fines without plugging using highly efficient countercurrent gas/solids contacting.

HYCRUDE Corporation recommends $0.50 million in FY '85 to investigate retorting of shale fines in a countercurrent baffled fluidized bed.

ADVANCED RESEARCH

Advanced Hydroretorting Studies

The process chemistry of moving-bed hydroretorting has been proven at the fundamental research level and because of the increased oil yield and quality obtained, advanced research is now warranted. Reduction of the hydrogen consumed in the process reduces both capital and operating costs. Methods for reducing the consumption of hydrogen in moving-bed hydroretorting should be further researched. The process economics can also be substantially improved by performing a sensitivity analysis on the entire system (shale mining, crushing, and all processing sub-systems) to ensure that the application of the most efficient systems for oil shale retorting have been included. Hydroretorting assays, continuous moving-bed hydroretorting tests, and detailed chemical analyses of products should be performed for a variety of Eastern oil shales to broaden the data base necessary for continued process development and environmental studies. Additionally, a preliminary study of the use of oil produced by moving-bed hydroretorting should be performed to evaluate its potential use for aviation turbine fuels or chemical feedstocks.

HYCRUDE Corporation recommends $1.85 million to be allocated to moving-bed hydroretorting advanced research projects.

Oil Shale Beneficiation

Beneficiation (enrichment) of the organic material (kerogen) in oil shale results in a more concentrated shale feed. The economic trade-off between beneficiation costs and the subsequent oil shale retorting costs should be evaluated for several processes in order to determine the optimum level of beneficiation.

HYCRUDE Corporation recommends $0.40 million in FY '85 to carry on advanced oil shale beneficiation studies.

Scaleability of Novel Eastern Shale Retorting Processes

The scaleup issues (oil yield versus equipment size) should be investigated for novel methods for Eastern oil shale retorting including fast heatup, fluidized bed thermal retorting, which has shown promising oil yields to date.

HYCRUDE Corporation recommends $0.25 million in FY '85 to carry out this work.

Gasification of Fines and Residue Shale

Oil shale fines and shale residue contain carbon which can be gasified in a spent shale-agglomerating fluidized bed to produce additional gaseous fuel. Potentially leachable material could also be immobilized in the form of non-leachable spent shale agglomerates.

> HYCRUDE Corporation recommends $1.00 million in FY ' 85 to investigate the gasification of Eastern oil shale fines and residue in a spent shale-agglomerating fluidized bed.

Auxiliary Process Studies

Advanced research work should be performed in several areas which are auxiliary to any Eastern oil shale retorting project. The method of preparation of oil shale feedstock by crushing and screening is important to all Eastern shale retorting technologies, as this consumes energy and generates fines which cannot be retorted utilizing presently available technology. Methods for oil shale crushing which minimize energy consumption and produce a closely controlled size range of crushed shale, thereby reducing fines waste, should be investigated.

It has been discovered by several researchers that there is a loss of oil yield potential from thermal processing after mined shale is exposed to the atmosphere (weathering) over periods as short as several days . It is important to investigate the extent of raw shale weathering as a function of exposure time, shale particle size, etc., so that appropriate action can be taken to prevent significant loss of potential oil yield. A research effort should be supported which investigates the cause and effect of raw shale weathering on retorting oil yields.

The efficient separation of water and fines from the oil produced during retorting is an important element of producing raw shale oil of consistent quality. Improved methods for separation of water and fines from shale oil such as the use of electrical fields should be developed and tested.

> HYCRUDE Corporation recommends $0.50 million in FY '85 to carry out advanced research projects on systems such as shale crushing, shale weathering, and oil/water separation which are ancillary to the retorting system itself.

ENVIRONMENTAL AND SOCIOECONOMIC STUDIES

Environmental Impacts of Hydroretorting

It is important during the development of an Eastern oil shale data base to ensure that the evaluation of environmental and socioeconomic impacts keeps pace with the growing knowledge of resources and processing methods.

A study should be conducted to further define the major environmental impacts of moving-bed hydroretorting and to develop process configurations which minimize these impacts in the most cost effective manner.

HYCRUDE Corporation recommends $0.40 million in FY '85 to carry out this work.

Environmental and Socioeconomic Studies

Since many environmental and socioeconomic issues are site-specific, they are a major concern of state and local governments. Except for instances in which research is conducted on one specific process, it is advised that monies to perform environmental and socioeconomic studies be allocated to the states which contain commercially promising oil shale deposits.

It is recommended that fundamental experimental studies be conducted to study the effects of differing retorting technologies and methods of mine reclamation or spent shale leaching.

During retorting, a significant portion of the sulfur present in the raw shale ends up in product gas and water in one form or another, and must be removed. Sulfur in the spent shale also has the potential to produce leachates. Techniques should be investigated to remove sulfur from raw shale prior to retorting which would eliminate the need for, or reduce the size of, sulfur removal processes.

The impact of re-contouring Eastern oil shale resource areas and expansion of their use for agricultural purposes should be studied. The effects on water balances and the social infrastructure should be examined.

It is recommended that preliminary studies be performed to identify areas which have the potential to be improved after land reclamation by revegetation with plant species which could not survive on the land before reclamation.

Studies should be conducted to determine the probable water requirements for a mature Eastern oil shale industry on a state-by-state basis, and the environmental impact of supplying those requirements should be investigated.

A preliminary study or studies should be performed to identify potential socioeconomic impacts of the area-wide development of an Eastern U.S. oil shale industry.

HYCRUDE Corporation recommends $1.6 million in FY '85 be allocated to the states which contain commercially promising Eastern oil shale deposits to conduct general environmental and socioeconomic studies of concern to a developing oil shale industry.

Senator **Domenici**. May I ask you a question, with reference to shale in the East, it is my understanding there is really one major project and that is in Kentucky. Are there other potential eastern oil shale projects in the works and do we need to make some special consideration and apply some special kind of assistance or rules to eastern shales?

Mr. **Schora**. Sir, the one program under the Synthetic Fuels Corp. that is under consideration, and I believe known as the Means project, and that is in Kentucky. That project utilizes a retort technique, basically thermal in nature, which is, I think, possibly well-adapted to western shales. However, we feel it falls quite short of realizing the potential for eastern shales.

With the newer type technology, we are talking about yields two to three times that which can be achieved with such thermal processes as are used in the Means project. I would say that we have looked at areas such as in Indiana and other States in addition to Kentucky, in which we feel there is potential for very significant projects.

Moneys are not presently being asked for by the SFC because at this point we consider that the technology was not quite to the stage where we could go before the SFC and viably ask for reasonable money.

Senator **Domenici**. In other words, the Synthetic Fuel Corp. as a sponsor and partial finance institution requires that you go to commercial production in your application to prove that will work. You are saying you are a little behind that curve, but nonetheless optimistic.

Ms. **Schora**. Yes, sir. we have technology which is behind the present status of development of the western type technologies. We feel we are not that far away. However, in talking with the people at the SFC, although they are very sympathetic with what we are doing and would like to find ways to fund this intermediate step, they are right now locked into processes or situations which want to go directly commercial.

Senator **Domenici**. Mr. Lawrence, president, American Gas Association.

STATEMENT OF GEORGE H. LAWRENCE, PRESIDENT, AMERICAN GAS ASSOCIATION

Mr. **Lawrence**. Mr. Chairman, Senator Ford asked Mr. Vaughan a moment ago if he thought the $1.3 billion electric R&D was out of balance with the $83 million gas R&D. We think it is. I would like to devote my few minutes here today to document that.

We used to think it was greatly out of balance when it was only about 8 to 1. Now it is 16 to 1. I think that one of the legacies of the National Gas Policy Act of 1978 which both of you gentlemen supported and I think the Nation should be grateful for that, because of all of the compromises and complexities it did do away with the inevitable gas supply shortage mentality.

We currently have an overavailability of gas supply. We are in an era now where price and competition and improved demand is more our problem. And much of the research that is in this gas-related research budget is devoted to improve efficiency and improving demand. I will leave to Dr. Lee and Mr. Webb to focus on certain of those things.

I would like to talk about what this R&D budget can do about greatly improving the long-term supply capability. To get that in focus, if the Strait of Hormuz were closed, there would be a cutoff of about 8 million barrels per day. It is my understanding that about 3 million barrels a day of that could be made up very quickly elsewhere, Mexico, Venezuela, Nigeria, and so forth, perhaps another 1 million from overland Saudi Arabia and transports, leaving about a 4-million-barrel-a-day cutoff.

With the repeal of the Fuel Use Act, which I think was a consensus formed in this Congress, and the available gas supply over deliverability today, we could replace 2 million barrels a day with that. I submit to you that with the research capability involved here, we could ensure the long-term remaining availability to supply the total 4 million barrels a day.

I would really like to focus on one particular area of greatest resource capability and it happens to be in the area where the administration's scalpel is most devastating. That is in the unconventional gas area. We asked for $22 million in our total budget of $150 million gas-related R&D. This is the bottom line of what was appropriated by the last Congress, $146 million. We asked for $22 million. They came up with a request of $8.5 million, about a third. The Congress appropriated maybe $13.5 million. Let us look at just a couple of areas at the potential in that tight formation area, for example. The potential resource is 500 trillion cubic feet. Some of the research that is already underway has indicated by just using through better research techniques some of the technology that is on the shelf today by down hole telemonitoring of some of the propping agencies as they go out through the formation fraction.

We can improve this recovery by as much as 20 to 25 percent. We are talking about 100 trillion cubic feet or adding 50 percent oil crude reserves. This is not drilling to 25,000 feet, it is not massive new risky exploration. This resource base is there. It is a matter of getting it out at commercial rates and we need a tremendous focus on R&D effort to that end.

Another area is the free methane and coal seams where the Morgan Town Lab estimates as much as 400 trillion cubic feet and the drilling techniques and the fracturing techniques could significantly improve the free methane recovery from just those two sources and the potential is huge.

So, again, Senator Domenici, Senator Ford, I submit to you that the gas-related R&D budget is not a problem budget. It is not overestimated to trade. It is one that our research people can use efficiently and it certainly needs to be removed and I think, again, what the administration has proposed greatly shortchanges the gas R&D.

Thank you.

[The prepared statement of Mr. Lawrence follows:]

STATEMENT OF
GEORGE H. LAWRENCE, PRESIDENT
AMERICAN GAS ASSOCIATION
BEFORE THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
ON THE DEPARTMENT OF ENERGY FY 1985 RESEARCH
AND DEVELOPMENT BUDGET
MARCH 12, 1984

Introduction

Mr. Chairman and Members of the Subcommittee:

The American Gas Association (A.G.A.) is pleased to present this statement on the gas-related research and development (R&D) projects conducted or funded by the Department of Energy (DOE).

A.G.A. is a national trade association comprising nearly 300 natural gas distribution and transmission companies serving more than 160 million consumers in all 50 states. Collectively, these companies account for nearly 85 percent of the nation's total annual gas utility sales.

A.G.A. recommends the appropriation of $150 million for DOE gas-related R&D in FY 1985. This level of funding is justified by the long-term, high-risk nature of the projects involved, the benefits that will flow from R&D work on these projects, and the need to develop a wide variety of future energy sources.

These recommendations are the product of careful evaluation of project needs by gas industry R&D experts. Members of A.G.A.'s Advanced Technology Task Group (ATTG) -- predominantly executives who are responsible for directing research at their respective companies or organizations -- assess the merits and status of projects which are considered to be appropriate for federal funding. The projects are considered to be appropriate because they are valuable to our national interests and private investment incentives are inadequate for the commitment of large amounts of capital. Projects and technologies which the ATTG believes will require federal funding are then reviewed and approved by the A.G.A. Technology Committee. The decisions of the Technology Committee appear in this document as recommendations to your Committee. The evaluations are coordinated with the Gas Research Institute (GRI) and the Institute of Gas Technology (IGT) so that the recommendations made to this Committee regard long-term, high-risk endeavors, although research projects conducted or funded by GRI and IGT include other types of projects. These recommendations do not duplicate projects funded by GRI.

Long-Term, High-Risk Projects

A.G.A. agrees with the Administration that the federal government should fund long-term, high-risk R&D that cannot be undertaken effectively by the private sector. Our selection process is designed to ensure that the projects for which we seek funding meet this criterion. Because they are large-scale and involve very sophisticated and novel technology, the projects frequently require 10 to 20 years to progress from the experimental to the operational stage. These long time frames discourage private sector investment because the payback on investment stretches over such a long period.

Moreover, rate regulation imposes another disincentive that discourages even the most strongly motivated companies. If a project is unsuccessful, the expenditures may be disallowed in the rate base as "imprudently" made. This shifts the expense entirely to the shareholders. On the other hand, the benefits of a successful project are enjoyed by ratepayers via reduced rates. Thus, the shareholders have a greater potential for loss than gain, so the risk related to R&D investment greatly discourages the allocation of capital to such projects. Consequently, federal funding is needed to conduct these projects.

Need for Balanced Research

Natural gas provides space heating for 55 percent of the country's households, 40 percent of the nation's total commercial energy market, and accounts for 36 percent of the energy consumed by American industry -- a larger share than any other single energy source.

These figures demonstrate that natural gas is an integral component of our national energy supply mix. We believe that the projects included in this proposal have the potential to increase greatly our future natural gas supplies. Based on this assumption, the increased funding that we are recommending is not only advisable, but necessary to ensure America's future energy independence.

Benefits of Gas-Related R&D

Basic applied research is a fundamental requirement for developing new, gas-related technologies that will someday benefit our nation. However, research does not always lead directly to commercial results, since it is inherently exploratory. This fact inhibits extensive support by regulated gas companies. In short, such research is time-consuming (and uncertain) because it is directed toward the exploration of new possibilities rather than the simpler task of building upon developed technologies. Consequently, research entails risks and time frames that rate-regulated entities cannot easily assume.

Although the gas industry sponsors significant basic applied research, additional federal participation is necessary to maximize the acquisition of new knowledge. This should lead to the basic discoveries that can provide commercial opportunities beyond those that are easily foreseeable today.

Initiating new technologies and improving existing ones will help to ensure the long-term security of plentiful gas supplies. Most major studies by industry and government currently forecast a national energy demand growth rate of 1.3 percent to 2.0 percent per year. Even at a rate of 1.5 percent per year, this means that, by the year 2000, United States requirements for energy will grow by about 30 percent over 1982 levels. Moreover, in 1982, the

U.S. imported about 30 percent of its petroleum needs. The projected increase in energy demand, combined with our current need to import some of our energy supplies, calls for the development of domestic supplies to the fullest extent possible. The current and foreseeable supplies of domestic natural gas are plentiful, but access to these supplies must be aided by increased R&D activities.

Beyond the strategic benefits related to increased gas use, natural gas can contribute to improved air quality. Natural gas combustion emits virtually no sulfur dioxide, unlike other fossil fuels. The total natural gas system, source to end user, produces minimal undesirable atmospheric emissions and does not have significant impact upon the deterioration of our lands and waters.

Funding Recommendations

A. COAL GASIFICATION: $43 Million

One important technology that can augment future natural gas supplies is coal gasification. Projections indicate that coal gasification, by the year 2000, may contribute approximately 0.3 Tcf to additional gas supplies with virtually no increase in R&D support. However, vigorous R&D support indicates that coal gasification may contribute up to 1.5 Tcf to our supplies.

Western coals and eastern coals differ in their characteristics and in the mining processes used to extract them. Thus, they must be handled with technologically different gasification processes. Eastern coal produced with underground mining machines contains significantly more fines than western coal produced by surface methods. Gasification technologies that can handle these fines need to be developed.

Contemporary technologies allow significant production of gas from coal. However, to take full advantage of our coal resources, we must develop alternative gasification technologies that are more closely tailored to the type of coal to be used and that will reduce the unit cost of the end product. Several advanced technologies that are progressing toward these goals are under development; however, significant advances must be made to overcome the technical problems presented and the high costs incurred by coal gasification.

B. UNCONVENTIONAL NATURAL GAS: $33 Million

Unconventional resources, such as incremental tight sands and Devonian shales, contain extensive amounts of gas. As with coal gasification, vigorous support of R&D programs for these resources can produce very substantial additional supplies by the year 2000. That is, up to 3.0 Tcf of gas could be produced from these resources with vigorous R&D efforts, while current levels of technology would produce approximately 0.3 Tcf.

Tasks which must be completed include verifying the size and distribution of the resources; developing effective methods of overcoming the low permeabilities which typically limit flow rates from tight sands and Devonian shale reservoirs; and developing and refining methods of precisely evaluating reservoir characteristics before and after stimulation operations. Determining the size and orientation of productive reservoirs can be aided by detailed geological mapping, core analysis, and improved seismic exploration as well as other geophysical techniques.

While advances in these areas continue, there is still much work needed. Effective production of gas from tight sands and Devonian shale will require an improved understanding of the mechanisms that control the flow of gas through the formations. Devonian shales and tight sands must be fractured to improve permeability, but the technologies for exploiting formations via this method are still in their infancy.

C. CONSERVATION: $22 Million

Two examples of items in this area are cogeneration equipment and natural gas vehicles (NGVs), whose development can lead to more efficient uses of gas by consumers and, as a result, greater national reliance on domestic resources. Although these two examples are not purely long-term, high-risk, as are the other projects recommended, we believe that they are important because their immediate impact on our energy resources and air quality is so significant that they should be continued.

Cogeneration -- the simultaneous production of electricity or mechanical energy and useful heat from a single fuel input source -- captures and utilizes waste heat energy from electric power generation. Depending on site-specific factors, cogeneration can offer substantial economic benefits and total energy savings over other combinations of heat and electricity production. However, relatively high start-up costs impede the widespread use of cogeneration. Improvements in the components of prepackaged cogeneration systems will lead to reduced capital investment and, consequently, will encourage more widespread use of cogeneration.

Broad development of natural gas vehicles will serve the national interest in the transportation market, where refined crude oil products currently enjoy a virtual monopoly. The use of NGVs could also lead to improved air quality, since NGV emissions of nonmethane hydrocarbons, carbon monoxide, and nitrogen oxide are only a fraction of the emissions produced by gasoline vehicles. Furthermore, unlike gasoline vehicles, NGVs emit almost no sulfur oxides or particulate matter. Fleet use of NGVs in congested cities would provide a significant benefit in those areas in which NGVs could make the most positive difference in air quality. However, use of NGVs is currently impeded by their limited fuel storage capacity and travel range; development of increased fuel storage capability would facilitate NGV use. Most importantly, development of new storage technologies should be pursued. For example, solid adsorbent systems could increase fuel storage capacity, without requiring larger fuel cylinders, while also decreasing the required compressor output pressure.

D. BIOMASS: $20 Million

Supplemental methane supplies from biomass and waste conversion can add significantly to total future gas supplies, since the supply of organic materials is virtually unlimited. Organic waste and biomass produced specifically for energy conversion are both viable sources of methane. Developing energy from organic waste would also provide the environmental benefit of productive use of currently "useless" materials. However, since organic waste supplies are generally not homogeneous, the uniformity of product gas quality and required pre - and post - conversion processing techniques are major concerns that currently limit the widespread use of this potential gas resource.

Biomass can also be cultivated specifically for conversion to gas and useful by-products, but farming, harvesting, and conversion technologies must be tailored to the specific feedstock. Research into all of these areas is vital to the expanded use of this most renewable gas resource.

E. FUEL CELLS: $20 Million

In a highly efficient electrochemical process, fuel cells convert the energy content of a fuel directly into electricity. For example, electrical conversion efficiency of fuel cells is approximately one-third greater than that produced by traditional generation of electricity. By combining fuel cells with cogeneration equipment, electrical and thermal conversion efficiency of 80 percent can be achieved, as opposed to only about 36-40 percent for energy delivered by a typical electric utility. Advanced concepts, to be commercially economical, require enhanced technology that focuses on using existing facilities for component evaluation, prototype endurance testing, measurement of contaminant effects, and proper electrolyte preparation in a controlled environment.

F. LIQUEFIED NATURAL GAS (LNG) SAFETY: $3 Million

The LNG resource base includes a very large worldwide gas reserve which is currently not committed to commercial use and is not expected to be committed in the near term. However, there is virtually no experimental data on the behavior of large spills of LNG. A.G.A. supports the construction of a national test site for evaluating spills of various materials, including LNG. One million dollars was appropriated in FY 1984 to begin construction of this facility; additional funds are necessary to carry the construction further. The research conducted at such a facility could simplify the safe handling of LNG and result in improved storage and tank design, thus making it easier to use LNG to supplement our gas supplies.

G. ADVANCED RESEARCH AND TECHNOLOGY DEVELOPMENT: $9 Million

Advanced gasification concepts, improved materials and catalysts, and more sophisticated instrumentation can lead to significantly improved products and processes in a number of technological areas. Further research into high-temperature, high-pressure, fluidized bed coal gasification is necessary to maximize the effective use of the resource and to optimize the economic attractiveness of such ventures. Such process development would also create a need for catalysts, materials, and instrumentation capable of withstanding the hostile environment within the gasification system.

Conclusion

A.G.A. believes that our plentiful supply of gas can be supplemented by developing technologies that improve our future gas recovery capabilities. The environment can benefit from gas use because gas is our cleanest fossil fuel. Furthermore, efficient use of gas can be encouraged by developing more sophisticated utilization technologies. However, because of the long time frames required to make these technologies operational, R&D projects must continue uninterrupted and must be funded at a level that allows full exploration of technological possibilities. The projects A.G.A. recommends for federal support can provide substantial supply, utilization, and environmental benefits.

Senator DOMENICI. Thank you very much. Your statement will be made a part of the record. We will get to you for questions shortly.

Mr. Philipp, director of research and development, Niagara Mohawk Power Corp., Syracuse. We welcome you this morning.

STATEMENT OF HOWARD PHILIPP, DIRECTOR, RESEARCH AND DEVELOPMENT, NIAGARA MOHAWK POWER CORP.

Mr. PHILIPP. Thank you, Mr. Chairman.

Senator Ford earlier mentioned his concern for sulfur acid precipitation. I would like to concentrate today on one option that many of the utilities in the country feel would be a solution for this concern. That is the fuel cell. Although the phosphoric acid fuel cell system technology has been significantly advanced by the joint efforts of the Government and the private sector, the largest funding requirements by far still remain in order to transfer this technology to practice.

The private sector cannot proceed without assurances of continuation of a Government partnership in technology advancement. The fuel cell technolgy represents the first completely new method of generating electricity to be placed in service since the introduction of the old steam and internal combustion cycles in the early 1900's.

I am sure you are well aware of its relatively benign and environmental impact compared with the thermal cycles that we are using today. Further, utility planners have already identified performance and operational benefits not available with current technology, particularly in such technical areas as efficiencies.

For these reasons, commercialization support of the fuel cell utility. The fuel cell users group has had a significant increase in membership and has been increasing its committee activity and personnel who are members of these committees. In addition, the new industrial fuel cell association was just formed as a similar users group to the utility industry for their interest in the chemical industries and other industries.

Further, there has been at least one commitment to the demonstration of the full scale fuel cell. My company is a utility that has given a verbal commitment. There is also an increasing interest in our fuel cell users group in the first commercial units that are being planned by the suppliers.

But technology is not yet ready to stand on its own. The technical risk is still evident. Take, for example, the Consolidated Edison problems in starting up and operating their 4.8-megawatt unit. The Westinghouse Electric Co. has had hurdles in their development of the fuel cell, of the phosphoric acid fuel cell.

We must have full scale testing of major components before we can assume the risk of the operations. We are also concerned about the research that is required for coal derived fuel uses in the fuel cell. In other words, the cost and performance objectives of the public private programs must be demonstrated.

I might add that the utilities are going to have to pay about $5,000 to $6,000 per kilowatt to install these demonstration units. Even a nuclear reactor does not cost that much.

Senator **Domenici**. I did not hear you.

Mr. **Philipp**. I said the utilities will have to pay about $5,000 to $6,000 per kilowatt to install these initial demonstration units as compared to about $600 a kilowatt for an already conventional device like the gas turbine. So this is the utility risk that the utilities are prepared to take, provided the research and development of the technologies are ready to reduce that risk, and they are not.

We believe that the technology program development of DOE must continue at a $30 to $35 million pace for this phosphoric fuel cell program.

Mr. Chairman, I have submitted a formal statement, which I would like also considered as part of the record.

Thank you.

[The prepared statement of Mr. Philipp follows:]

STATEMENT ON THE FY 1985 FUEL CELL BUDGET
OF THE DEPARTMENT OF ENERGY

HOWARD PHILIPP

DIRECTOR, RESEARCH AND DEVELOPMENT

NIAGARA MOHAWK POWER CORPORATION

SYRACUSE, NEW YORK

Mr. Chairman, I am Howard Philipp, Director of Research and Development for Niagara Mohawk Power Corporation in Syracuse, New York; the utility with the largest energy sales in New York state. Our company has already expressed a commitment to purchase one of the first commercial prototype fuel cell plants.

I thank you for this opportunity to present, on behalf of the Fuel Cell Users Group of the Electric Utility Industry, Inc. (the Users Group, described below in more detail), these brief remarks on the Department of Energy's FY 1985 budget for the phosphoric acid fuel cell.

First, I want to acknowledge the strong support you and your colleagues on this Committee have shown for the fuel cell over time. Had it not been for your faith and patience, this technology would not have achieved the advances of recent years.

The faith of the utility industry also remains strong, as indicated by the new resolution on "Research for Growth and National Security" (Attachment 2) passed by the full membership of the National Rural Electric Cooperative Association. The nation's utilities remain solidly committed to the advancement of the fuel cell as a powerful "tool for growth." Further indication of the broad interest in this technology is the recent formation of the Industrial Fuel Cell Association, a group established to promote the application of fuel cells in chemical and other industry plants.

I'm sorry to report, however, that the Administration has yet to acknowledge that this is not a proven technology. The appeal to DOE Secretary Hodel for greater continuity of support for this public/private partnership, from the fuel cell users groups of both the gas and electric utility industries (Attachments 3 and 4), did not produce a more balanced federal budget request for FY 85. The Department of Energy fuel cell budget request bears no relationship to the Department's existing program commitments. At $13.7 million, FY-85 requested funding is down 67.8 percent from the $42.6 million appropriated for this line item in FY 1984.

I understand that the Department of Energy has justified this cut on the assumption that the fuel cell is ready for commercialization. As you are well aware fuel cell technology still requires substantial development to achieve commercial service.

The Fuel Cell Users Group of the Electric Utility Industry, Inc. is a four-year old organization with a membership of 56 utilities (and 8 Associate Members) spanning the privately, publicly, and cooperatively owned electric utility industry. A list of our membership is included as Attachment 1. Cumulatively, the members of the Users Group represent about 40 percent of the U.S. generating capacity. We are united in the interest of encouraging and supporting research, development, and demonstration leading to the ultimate commercialization of the phosphoric acid fuel cell power plant.

Although it has achieved many of its objectives (summarized in Attachment 5), the 4.8 Mw project in New York City is experiencing difficulties in start-up. During an attempt to produce power in late December of 1983, one of the 20 cell stack assemblies in the power plant experienced a cooling system failure which prevented the plant from becoming fully operational. A decision has now been made by the project management group (DOE/EPRI/ConEd) to replace the failed stack with a spare produced under the original power plant fabrication program.

While an attempt to operate the 4.8 Mw plant for an extended period will follow the installation of a spare stack, it should be noted that the New York site is equipped with an early cell stack configuration with limited "shelf" life. An improved cell configuration has been developed to address this known deficiency, but it came too late to be incorporated in the New York site. A sister machine of the New York power plant was built in Tokyo specifically to evaluate this improved cell technology.

I am pleased to report that the 4.8 MW unit being demonstrated by the Tokyo Electric Power Company (TEPCO) in Japan attained full rated power earlier this month and has now completed its initial validation testing. Every effort is being pursued—specifically, through an agreement executed between the United Technologies Corporation (UTC) and the Electric Power Research Institute (EPRI)—to enable participants in the U.S. fuel cell development effort to obtain full information and maximum advantage from the TEPCO program.

The technical risks so evident in these UTC demonstrations require continued federal support, but the utility industry is still preparing for commercialization.

Taking advantage of the experience in its demonstrations and incorporating advances in the technology achieved since 1976, UTC has designed and is developing an 11 MW commercial power plant. EPRI and the Users Group have participated in the conceptual stages of the design effort. Two domestic utilities have completed site-specific installation studies of this configuration. UTC plans to achieve production capability by the end of this decade. Entering the marketplace with a combination of prototypes and semi-production units will involve private-sector risk sharing by the utility industry and the manufacturer.

The Westinghouse Electric Corporation is in the technology development stage and has required performance improvements to overcome some technical hurdles that have been encountered. Nevertheless, Westinghouse is currently designing two 7.5 MW fuel power plants for installation at two host utility sites. One of these units will be electric only while the second will be used in a cogeneration application. Each plant will use gas-cooled cell stacks. The conceptual design for these plants is complete and has received a thorough review by the Fuel Cell Users Group. Delivery and installation of these units will take place in late-1986 and mid-1987.

Although commercialization support is building, the recent developments in UTC's demonstrations and Westinghouse's development program suggest that the fuel cell is far from achieving technical maturity, as the Administration would have us believe. Significant research and development work remains to be done. Accordingly, we estimate that--rather than the $7.2 million set aside for the phosphoric acid program in the Administration's FY 85 request--a prudent amount would be $25-30 million for the electric utility (multi-megawatt) activity. We understand that the on-site (40 kW) fuel cell program requires an amount comparable to that ($5 million) appropriated in FY 84, so that the entire phosphoric acid fuel cell appropriation should be approximately $30 to 35 million.

The fuel cell is worthy of continued Congressional support. A recent report by the Users Group for the Department of Energy under DOE Cooperative Agreement (#DE-FC01-82FE60018) identifies the significant advantages of this type of power production.

- With the fuel cell, utilities will be able to add increments of generation that track demand better than what is possible with larger baseload units, thus reducing the risk and financial exposure in capacity planning decisions.

- Fuel cells will go into operation sooner than units with longer leadtimes, thus improving earnings quality by limiting interest during construction.

- Operational advantages of the fuel cell include: load following, VAR control, and spinning reserve. These features combined with transmission and distribution savings due to siting near the load represent a credit of up to $125/kW of capacity.

- Cogeneration (the simultaneous production of heat and power) has a strongly positive effect on both prospective market size and share. Cogeneration credits have been estimated as high as $220/kW capacity.

- Fuel cells will be more easily sited than units with less benign environmental characteristics.

Prominent among the attractive features of the fuel cell is its minimal environmental impact, which should be of particular interest to those in Congress reviewing environmental policy and legislation. "Phosphoric acid, fuel cell power plants have low air emissions, require little or no water, and are relatively quiet," according to a report recently published by NASA for the DOE. This report, Assessment of the Environmental Aspects of the DOE Phosphoric Acid Fuel Cell Program (May, 1983 NASA #CR-168131), concludes the following with respect to air quality:

> "...The generation of electricity is responsible for the production of more particulates, sulfur oxides, and nitrogen oxides than all other

> stationary sources combined. In addition, about one-third of the hydrocarbon and carbon monoxide emissions from stationary sources originate from power generation systems. Even with the installation of the most advanced pollution-abatement equipment on new fossil-fueled power plants (particularly coal-fired), air pollutant emissions remain three to four orders of magnitude greater than those projected for similarly sized fuel cell systems. Therefore, sizable improvements in national air quality can be expected when fuel cells penetrate the energy supply market in substantial quantities. Since it is highly probable that fuel cell utilization will initially occur in areas of poor air quality (close to the load in urban areas), the air quality benefits of fuel cell systems are more likely to be focused where most needed."

If these fuel cell benefits are to be realized, developmental risks must be taken. We respectfully request a sustained sharing of these risks by the federal government.

Mr. Chairman, I thank you and the Committee for your undiminished interest in and longstanding support of this attractive technology. I encourage your continued funding for the next few critical years. I'll be be happy to respond to any comments or questions on these remarks.

FUEL CELL USERS GROUP MEMBERS

Federal Government Utilities

Bonneville Power Administration
Tennessee Valley Authority

Cooperatives

Adams Electric Cooperative
Allegheny Electric Cooperative
Brazos Electric Power Cooperative
Buckeye Power Inc.
Colorado-Ute Electric Association, Inc.
Hoosier Energy Division, REC, Inc.
Lee County Electric Cooperative
National Rural Electric Cooperative Association
Seminole Electric Cooperative
Southern Maryland Electric Cooperative
United Power Association

Municipals

American Public Power Association
Anchorage Municipal Light & Power
Arkansas River Power Authority
Easton Utilities Commission
Jacksonville Electric Authority
Lincoln Electric System
Los Angeles Dept. of Water, Power & Light
Massachusetts Municipal Wholesale Electric Company
Memphis Gas, Light & Water
Missouri Basin Municipal Power Agency
Palo Alto Electric Utility
Provo City Power
Santa Clara Electric Department
Taunton Municipal Lighting Plant

Investor Owned Utilities

Baltimore Gas & Electric Company
Boston Edison Company
Central Hudson Gas & Electric Corporation
Central Illinois Light Company
Consolidated Edison Company of New York
The Dayton Power & Light Company
Delmarva Power and Light Company
Duquesne Light Company
Edison Electric Institute
Green Mountain Power Corporation
Hawaiian Electric Corporation

Idaho Power Company
Kansas City Power and Light Company
Long Island Light Company
Mississippi Power and Light Company
Niagara Mohawk Power Corporation
Northeast Utilities Service Company
Ohio Edison Company
Philadelphia Electric Company
Public Service Company of Oklahoma
Public Service Electric and Gas Company
San Diego Gas & Electric Company
Southern California Edison Company
Southern Company Services
Tampa Electric Company
Toledo Edison Company
Utah Power & Light Company
Virginia Electric Power Company

Foreign

Hydro-Quebec

Associate Members

Burns & McDonnell Engineering Company
Burns & Roe, Inc.
Ebasco Service Inc.
Johnson Matthey Research Centre
Kinetics Technology International Corp.
New Energy Development Organization
NUS Corporation
Stone & Webster Engineering Corporation

Attachment 2

NRECA Annual Meeting 1984

RESOLUTION NO. J-2

FROM: Research and Technological Development Committee
APPROVED BY: Resolutions Committee

SUBJECT: Research for Growth and National Security

We support a well-funded, long-range commitment for Electric Energy Systems (EES) research and development and fuel cell development. These areas have national security implications as well as the potential for providing opportunities for growth and energy self-sufficiency.

We therefore urge the Administration and Congress to provide the following:

> Minimum funding of $20-million for FY 85 for Electric Energy Systems research within the Department of Energy. EES is involved with several programs of critical national importance. Among them is the study of the effects of electromagnetic pulse (EMP) which, in the event of a strategic military weapon explosion in the atmosphere, could result in a pulse from gamma rays that could create a surge 10 to 100 times faster than a lightning stroke. Such a pulse could disrupt communications and immobilize the entire electric industry. Other EES projects which require strong support include system technologies involving improving efficiencies and reliability of power generation, transmission and energy storage, and the electric field effects of high voltage transmission lines.
>
> A five year commitment, with a minimum of $40-million for FY 85, for fuel cell research and development. The potential offered by fuel cell technology for highly efficient, dispersed electric power generation (so essential to national security) is enormous. Along with the potential economic advantages, the fuel cell has other very desirable characteristics (environmentally benign, short lead time for installation, modular design, and favorable load-following capabilities) which makes it truly a "tool for growth."

Attachment 3, Page 1

Onsite Fuel Cell
Users Group
of the Gas Utility
Industry

BOARD

Chairman
Elwin S. Larson
Executive Vice President
Brooklyn Union Gas
(212) 403-2000

Vice Chairman
Ronald T. Miller
President and CEO
Northwest Natural Gas
(503) 226-4211

MANAGING COMMITTEE

Chairman
Victor M. Richel
Vice President
Elizabethtown Gas
(201) 289-5000

Vice Chairman
Joseph A. Pelletier
President
Gasco, Inc.
(808) 547-3103

Executive Director
Vincent B. Fiore
Director
Gas Research Institute
(312) 399-8235

8600 West Bryn Mawr Avenue
Chicago, Illinois 60631

August 26, 1983

The Honorable Donald Paul Hodel
Secretary
U.S. Department of Energy
1000 Independence Avenue, S.W.
Room 7A-257
Washington, D.C. 20585

Dear Secretary Hodel:

Over the past sixteen years, the electric and gas utilities, both directly and through the Electric Power Research Institute (EPRI) and the Gas Research Institute (GRI), have invested over $150 million in phosphoric acid fuel cell (PAFC) power plant development. The private sector level of interest and financial support continues to grow as fuel cell technology comes closer to commercialization. The fuel cell program has also enjoyed broad and consistent support by Congress over the last four years. In contrast, DOE's funding support has been disappointing. As the joint DOE/industry fuel cell technology program begins the critical final step, it is essential that DOE not only request funds in its FY 1985 budget to meet its existing contractual commitments but also that DOE promptly commit funds already appropriated in the FY 1984 budget.

The electric and gas utilities are pursuing PAFC technology for two related but different applications. One application, of interest to gas and gas-electric (combination) utilities, is for small (40-300 kW) onsite generators located in commercial and multifamily residential buildings. Such plants, using pipeline gas as a fuel, could supply both electric and thermal energy, consuming no more fuel than that now required for thermal demand alone. The other application, of interest to the electric utilities, is for multimegawatt, dispersed generators located on the utility grid with the potential for waste heat recovery. These generators could use available fuels more efficiently and cleanly than any alternative peaking or load following generator.

In recognition of the potential of this option, within the past three years, over 75 electric and gas utilities have formed fuel cell users groups (The Fuel Cell Users Group of the Gas Utility Industry and The Fuel Cell Users Group of the Electric Utility Industry, Inc.) to expedite the development and commercialization of PAFC power plants (see attached member list). The development phase of the program involves joint contracts with DOE, EPRI, and GRI. The users groups provide a direct link to the electric and gas utilities which must implement the commercialization of the technology.

To resolve the question of the appropriate federal role, both EPRI and GRI adapted their fuel cell programs and funding to be consistent with the Administration's principles for federal research and development criteria. GRI, for example, assumed total funding responsibility in FY 1983 for the joint DOE/GRI 40 kW onsite fuel cell field test activities and provided 50 percent of the funds for a coordinated DOE/GRI onsite fuel cell technology development program. Therefore, we are confident that the PAFC program meets the Administration's criteria for continued DOE funding. In fact, this is evidenced by the comprehensive fuel cell R&D program DOE has planned. This Administration has signed more fuel cell R&D contracts, both in terms of dollars and numbers of contracts, than any previous Administration.

With the FY 1984 DOE budget process coming to a close and the initial planning for the FY 1985 budget being initiated, we wish to take this opportunity to discuss with you a disconcerting pattern in the DOE fuel cell program that has caused our members considerable concern during the past year. One concern is that there appears to be no link between contract funding requirements and the OMB allowance for the DOE fuel cell budget request. The other is the delay that has been experienced in contracting for new funds appropriated by the Congress. These problems not only impact the initiation and continuity of funded programs, but also impair the ability of the funding partners (EPRI and GRI) to plan and coordinate their research programs properly.

While DOE has planned and executed contracts necessary for a sound fuel cell program, there has been a breakdown between the contractual funding requirements and the budget requests for these activities. For instance, despite a cofunding agreement with GRI and a contract with United Technologies Corporation (UTC), DOE requested no funds for the 40 kW onsite technology development program in either the FY 1983 or FY 1984 budgets. Similarly, contract funding requirements for the electric utility program were $22 million in FY 1984, while the DOE budget request was for only $3 million.

Similarly, a significant portion of funds appropriated in FY 1980 through FY 1982 for new development work was not obligated for a year or more, leaving large and unproductive unobligated balances in the fuel cell program. The FY 1984 appropriations will likely authorize work beyond existing contract amounts. In view of the short time available to complete development work on the commercial prototype fuel cells, prompt obligation of these funds is important.

We hope that DOE is prepared to see the PAFC technology development through to completion in continuing partnership with industry. As an essential step in doing so, we believe that DOE should seek sufficient funds in FY 1985 to service the existing fuel cell contract program. With continued support by DOE, PAFC power plants will be commercially available within the next five years. We strongly encourage you to join U.S. electric and gas utilities and the Congress to provide adequate support for this important program. We would like to meet with you in the near future to discuss this situation and to see how we can work together more effectively.

Sincerely,

E. S. Larson
Elwin S. Larson
Chairman, Fuel Cell Users Group
of the Gas Utility Industry

Lelan F. Sillin, Jr
Lelan F. Sillin, Jr.
Chairman, Fuel Cell Users Group
of the Electric Utility Industry

Attachment

Attachment 4

THE SECRETARY OF ENERGY
WASHINGTON, D.C. 20585

November 15, 1983

Mr. Lelan F. Sillin, Jr.
Chairman
The Fuel Cell Users Group
of the Electric Utility Industry
1101 Connecticut Avenue, N.W.
Washington, D.C. 20036

Dear Mr. Sillin:

Thank you for your letter of August 26, 1983, regarding the Department of Energy's (DOE) fuel cell program and the views on the program by the fuel cell users groups established by the gas utility and the electric utility industries.

I share your views in terms of the potential benefits that could be derived from the successful development of fuel cell systems. The DOE has and will continue to place high priority on the pursuit of an aggressive fuel cell program. The fuel cell funding needs, however, must be weighed against similar requirements in other energy research and development programs to preserve program balance and against national economic priorities (which necessitate fiscal restraint in the allocation of research and development funds). In this context, difficult decisions always arise regarding relative funding priorities. While recent fuel cell budget requests by the Administration have been lower than in prior years, they have been adequate to continue fuel cell technology development and have reflected the view that phosphoric acid systems technology has been sufficiently advanced by the joint efforts of the Federal Government and the private sector that the Federal role can be diminished in this area.

Regarding your comment on the need for prompt obligation of fuel cell funds appropriated by the U.S. Congress, we believe that significant progress has been made in obligating these funds during Fiscal Year 1983. As of September 30, 1983, DOE has obligated nearly all available phosphoric acid fuel cell funds appropriated by Congress through Fiscal Year 1983. Fiscal Year 1984 Departmental obligations will be handled in an equally expeditious manner.

I appreciate your personal interest in the fuel cell program, as well as the efforts of the users group that you chair in advancing this very promising technology.

Sincerely,

Donald Paul Hodel

DONALD PAUL HODEL

RECEIVED
NOV 28 1983
LELAN F. SILLIN, Jr.
CHAIRMAN OF THE
EXECUTIVE COMMITTEE

4.5 MW FUEL CELL POWER PLANT DEMONSTRATION

New York City

1984 Update

Prior to 1983 the fuel cell demonstration project achieved two of its major objectives. First, it received siting authorization as a power plant in one of the most densely populated and environmentally sensitive areas in the country. Local groups, while initially expressing concern about public safety, learned more about the technology and its potential benefits and ultimately agreed to the facility's construction. Second, the plant was factory fabricated and installed on site by a utility using traditional methods.

Also prior to 1983, this first-of-a-kind power plant experienced extraordinary test requirements mandated by local authorities and damage to three key components due to material failure, water freezing after required hydro testing and loose insulation deflecting the flame of two start-up torches directly onto key elements in the fuel processing system. These difficulties resulted in about 2-1/2 to 3 years of delays. However, these obstacles were overcome through modified designs, new materials, revised testing procedures and other changes and innovations.

During 1983 the most important operational step toward producing electricity took place. This was the completion of the Process and Control Test, or PAC Test. The purpose of this test is to prove out the processing of the fuel into the hydrogen rich gas required by the fuel cells. It is also during PAC Test that all of the auxiliary systems and components are exercised for the first time and operated as a unit. Additionally, it provides the opportunity to cycle the fuel processing system several times, thereby verifying the repeatability of the system to perform properly. Stable operation of this system was achieved on June 8 and the PAC Test was successfully completed on June 17, 1983.

Another major step accomplished during 1983 was successful testing of the Power Conditioning System. This system converts direct current electricity into the alternating current used by most utility consumers. This accomplishment was preceeded by the usual difficulties encountered in debugging electrical devices of new designs, such as component failures, undersized electrical components, and electrical interference in logic circuits. Thermal stability tests and a 100-hour operational test successfully culminated this test activity in March, 1983.

After completion of these tests the fuel cells were installed and the production of electricity was attempted in late December 1983. Data collected during this attempt indicates that one fuel cell stack assembly has been rendered unuseable due to an internal water leak. Data also suggests that some of the 5-year old first generation fuel cell stack assemblies, while operable, are showing signs of "old age". The next attempt to start-up has been postponed while this situation is studied and evaluated. The next attempt may not begin until April 1984.

A similar 4.5 MW power plant from the same manufacturer but using improved fuel cell stack assemblies benefitted from the difficulties encountered in New York City and is now operating as a test unit in Tokyo, Japan, just three years after it was ordered. Operating data from this unit may be made available to U.S. utilities later this year.

It is important to note that much learning has already been attained from the New York demonstration. As significant as these technical achievements are, however, the production of electricity is still the goal in New York City. Its operation is expected to be useful for establishing utility confidence in the technology base and utility willingness to proceed with the high risk commercial prototype power plant purchases.

Achieving our mutual goal of commercialization of this technology still requires costly fabrication, construction and start-up testing of the first-of-a-kind commercial prototype power plants. The federal support has been instrumental in the development of the technology base. Prior to the private sector acceptance of the commercialization risks and costs, however, the technology programs must achieve their cost reduction goals and key component and system tests must be conducted.

Senator **DOMENICI**. It will be made part of the record. Thank you very much.

David Webb, Gas Research Institute, Washington, DC.

STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT, POLICY AND REGULATORY AFFAIRS, GAS RESEARCH INSTITUTE

Mr. **WEBB**. Thank you very much, Mr. Chairman and members of the committee. I appreciate the opportunity to appear before you today to discuss the Gas Research Institute's views regarding the needs for research funding for the industry in the DOE funding for 1985. The gas industry, as Mr. Vaughan has already told you, is recommending a total of $150 million.

The gas industry cofunds and coordinates many of its research programs with DOE, therefore, the actions of Congress on the fiscal year 1985 DOE budget do have a direct impact on the gas industry's research programs.

The gas industry recognizes in today's environment of limited financial resources and large Federal budget deficits that competing requests for Federal support and funding must be carefully evaluated and hard choices made. Therefore, before I discuss three specific budget recommendations, let me discuss four of the five key factors that we use for trying to determine the reasonableness of our request in setting our priorities.

First, is the DOE budget request for gas research consistent with congressional actions over the past 3 years? In our opinion, it is not. The DOE fiscal year 1985 budget request for gas-related research is only $84 compared to the $132 million approved by Congress just 5 months ago, in other words, only 65 percent of the amount previously approved.

Second, has the gas industry responded to Federal policy by increasing our own research budget and by picking up more of the near-term research? Yes, we have, Mr. Chairman. The gas industry through GRI has been totally responsive to Federal policy. We have focused our research on near term, increased our budget over 75 percent in the past 4 years from the level of $81 million in 1981 to $140 million in 1985.

Mr. Vaughan has already touched on the imbalance of the DOE budget. However, one of the other factors we used are, are there institutional barriers that prevent the regulated gas industry's ability to fund R&D? There are barriers, Mr. Chairman. A little over half our primary energy finds its way to customers through the electric and gas utilities. Both these regulated industries have weak incentives to spend on R&D. If successful, the benefits go to ratepayers; if unsuccessful, the expenditure may be disallowed as imprudent.

DOE recognizes structural problems for the electric industry in their budget request by requesting $1,320 million. However, the same structural deficiencies for the gas industry are ignored as they only requested a total of $84 million. This must be corrected by funding a viable, long-term gas-related research program.

Finally, Mr. Chairman, are the gas industry's fiscal year 1985 budget recommendations consistent with Federal policy and congressional direction? Yes, they are. You will find that they are in the national interest. Essentially, they are proposing to continue projects already underway, previously approved by this subcommittee and Congress. Also, their recommendations do not include large-scale demonstrations, near-term research or commercialization activities. Therefore, we do not feel that they are in conflict with Federal energy policy.

At the end of my testimony is a budget table that provides the details but let me briefly mention three long-term research programs that we think require continued joint DOE/gas industry projects. The fossil energy program in the area of surface coal gasification. The gas industry is recommending $32.5 million. The specific increases we are recommending are to continue advanced processes being developed by industry to develop our eastern ash agglomerating coals.

Federal support of $7 million in fiscal year 1985 is needed for further development of the Westinghouse process being conducted in Waltz Mill. Six million dollars are required to continue the pressurized ash agglomerating process at IGT to extend this technology to additional high-sulfur bituminous coals.

In the area of fuel cells, the gas industry is recommending a total of $20 million of which $6 million is specifically recommended to continue DOE, GRI phosphoric acid onsite fuel cell program. The gas industry and GRI have now assumed the total responsibility for all the near-term costs of this onsite phosphoric acid fuel cell system work.

We have increased our budget from $11 million in 1982 to a level of $19.6 million in both 1983 and 1984 to offset the loss of DOE funds. However, the continued funding of the required long-term technology development must be a combined DOE and gas industry responsibility. We initiated a 4-year program with DOE in 1982 in a 50–50 cost shared program to continue this research. This would require a budget of $6 million from DOE for fiscal year 1985, to match the $6 million the gas industry has committed for this program.

Finally, Mr. Chairman, in the area of conservation, the gas industry is recommending an expanded advanced gas prime mover heat pump program, primarily to bring the heat pump technology to those 40 million users that use gas to heat their homes today. Specific money is needed to continue technology research on the free-piston Stirling engines program, the free-piston internal combustion engine program, and the double-effect absorption cycles program.

To offset the $7 million we are recommending in the DOE budget, the gas industry is committing to spend over $5 million in both 1984 and 1985 for the near-term aspects of these same programs.

In summary, Mr. Chairman, a viable Federal program consistent with the administration's energy policy and complementary to the gas industry's increasing near-term research program requires a budget of $150 million in fiscal year 1985 for long-term gas-related research in fossil, conservation, and solar programs.

I thank you, Mr. Chairman, and would like to request that my full statement be inserted in the record.

[The prepared statement of Mr. Webb follows:]

STATEMENT OF DAVID O. WEBB, SENIOR VICE PRESIDENT
POLICY AND REGULATORY AFFAIRS, GAS RESEARCH INSTITUTE
BEFORE THE ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE OF THE COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
MARCH 12, 1984

Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear before you today to discuss the Gas Research Institute's (GRI) views and FY 1985 budget recommendations necessary to allow the Department of Energy (DOE) to continue critical, long-term gas-related research programs. The gas industry is recommending a total of $150 million for gas-related research in the DOE budget. We are recommending $97 million for gas-related research for DOE's Fossil Energy Program, $22 million for DOE's Conservation Program, and $31 million for DOE's Solar and Renewables Program. These budget recommendations are essentially the same as appropriated by Congress for FY 1984 and are in accord with the Administration's stated energy policy, complement the current research programs funded by the gas industry, and are consistent with the previous initiatives and leadership actions taken by this subcommittee and Congress to insure a viable long-term gas research program in the Department of Energy.

GRI is an independent, not-for-profit scientific research organization created by the gas industry in 1976 to plan, finance, and manage an expanded and fully coordinated gas-related research and development (R&D) program for the mutual benefit of the regulated gas industry and its ratepayers. In compliance with stipulated procedures, GRI submits its annual plan and five-year R&D program to the Federal Energy Regulatory Commission (FERC) for review and approval as part of a public proceeding. GRI cofunds and coordinates many of its research programs with DOE; therefore, the actions of Congress on the FY 1985 DOE budget have a direct impact on the gas industry's research program.

The need for a balanced, consistent federal policy that provides adequate funding for long-term gas research is absolutely essential if industry is to assume the near-term research previously funded by the federal government. Industry requires a stable and consistent federal base against which to plan its own research programs.

According to DOE's projections, the U.S. will continue to rely on gas and oil for over 50 percent of its energy needs in the year 2000. As we approach the year 2000, adequate gas supplies will depend on development of advanced technology necessary for the successful conversion of supplemental sources. Establishing the required technology base to develop these supplemental gas supplies at cost-competitive prices requires a lead time of six to fifteen years depending on the resource. In other words, we must start now.

I recognize in today's environment of limited financial resources and large federal budget deficits, that competing requests for federal support and funding must be carefully evaluated and hard choices made. Therefore, before I summarize specific budget recommendations, I will discuss five key factors GRI used for establishing the priority and evaluating the reasonableness of our recommendations.

1. **Is the DOE budget request for gas research consistent with congressional actions over the past three years?**

Congress, during its review and approval of the DOE budget during the past three years, has consistently added funds to the Fossil Energy, Solar, and Conservation programs to continue long-term research projects in coal gasification, onsite fuel cells, unconventional natural gas, biomass, industrial cogeneration, and heat pumps. Last year Congress more than doubled funding for the Fossil, Solar, and Conservation budgets and provided approximately $132 million for gas-related research. This year's DOE budget requests only $84 million in these programs for gas-related research and omitted funds necessary to continue many critical ongoing projects.

CONGRESSIONAL APPROPRIATIONS FOR DOE GAS-RELATED RESEARCH
($ Millions)

	FY 1982	FY 1983	FY 1984	DOE Request FY 1985
FOSSIL ENERGY				
Advanced Research and Technology Development	$ 12.5	$ 7.4	$ 12.00	$ 12.00
Surface Coal Gasification	53.1	39.0	36.80	15.00
Underground Coal Gasification	8.3	6.0	6.00	5.85
Unconventional Gas Resources	8.7	13.9	13.50	8.55
Fuel Cells (Gas-Related)	5.6	14.0	16.20	7.90
Eastern Oil Shale Gasification				0.00
LNG Safety	6.3	3.5	3.25	2.00
SUBTOTAL	$ 94.5	$ 83.8	$ 87.75	$ 51.30
GEOPRESSURED METHANE	$ 17.3	$ 8.4	$ 7.00	$ 3.50
BIOMASS	$ 3.0	$ 4.0	$ 13.00	$ 13.00
CONSERVATION	$ 10.5	$ 4.0	$ 24.25	$ 15.90
TOTAL	$125.3	$100.2	$132.00	$ 83.70

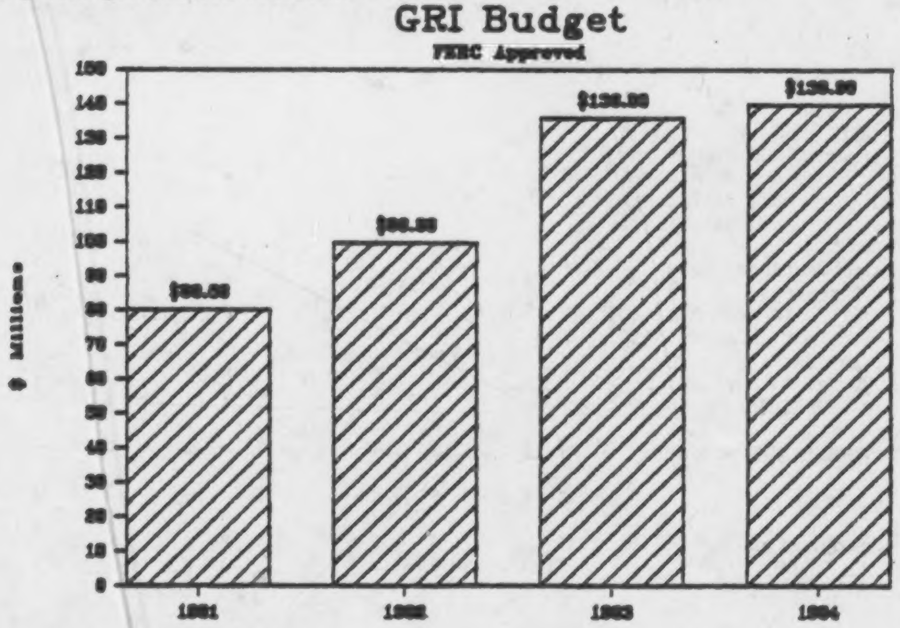
The DOE FY 1985 budget request for gas-related research is not consistent with congressional policy as it is only approximately 65 percent of the level approved by Congress for FY 1984 just five months ago.

2. **Has the gas industry increased its own research program with emphasis on near-term research?**

In contrast to the inconsistency in federal policy and the reduced DOE funding for gas research, the response of the gas industry to the revised R&D policy has been rapid and very impressive. GRI's research program and budget has grown from $80.5 million in 1981, the first year the federal policy shifted responsibility for near-term research to industry rather than DOE, to $140 million in 1984. This growth is even more impressive when you consider that the gas industry in 1983 sold less gas than any year since 1967. The gas industry is keeping its commitment to research.

Also, in response to federal action to terminate many near-term projects, the GRI budget has continually shifted to more near-term research. In 1984 over 75 percent of the research budget is devoted to near-term projects. Therefore, if the DOE budget does not provide funding for the continuation of long-term gas research, that research will not be adequately funded.

GRI's emphasis on near-term research has resulted in significantly increased cofunding from the manufacturing sector. Industry coordinated funding has increased from a level of $8.8 million in 1979 to approximately $31 million in 1983. However, GRI's experience with industry cofunding strongly indicates the majority of these coordinated funds will always be in areas that have the potential to be commercialized within five years. This also reemphasizes the need for DOE to provide a stable and viable funding base for necessary long-term gas-related research.



The gas industry through GRI has been totally responsive to federal policy by focusing on near-term research and increasing its total budget by 75 percent over the past four years.

3. Is the DOE budget request balanced or is it biased toward specific technologies?

To illustrate the importance of providing a balanced federal gas research program, in last month's testimony on the DOE budget, Secretary Hodel stated, "The overall goal of national energy policy is to foster an adequate supply of energy at reasonable costs. The policy recognizes that adequate supply requires flexibility in the energy system, with no undue reliance on any single source of supply." GRI agrees with this policy. However, for this policy to work and to prevent overreliance on any one energy source, DOE must provide reasonably balanced funding for competing energy technologies. An examination of the DOE FY 1985 budget request reveals that again the budget is tremendously biased in favor of electric technologies with particular emphasis on nuclear. This bias toward funding electric-related research of greater than 15 to 1 compared to funding of gas research has been evident in the DOE budget for the last ten years and conflicts with the Department's policy.

The DOE budget is not balanced and is strongly biased toward funding electric options.

4. Are there institutional barriers that limit the regulated gas industry's ability to fund R&D?

DOE's Energy Research Advisory Board (ERAB) in a report to the Deputy Secretary of Energy put these factors in proper perspective in its study Federal Energy R&D Priorities.

> A little over half our primary energy finds its way to consumers through the electric and gas utilities. . . . Both these regulated industries have weak incentives to spend on R&D. If successful, the benefits go to ratepayers; if unsuccessful, the expenditure may be disallowed as "imprudent." (Emphasis added).

DOE in its FY 1985 budget request recognized this structural problem for the electric utilities by proposing a total electric-related research budget of approximately $1,320 million. However, they totally ignored these same institutional and structural deficiencies for the regulated gas industry by proposing only $83.7 million for gas-related research. A ratio of over 15 to 1 is not sound national policy. This imbalance must be corrected by funding a viable gas-related research program.

DOE FY 1985 BUDGET REQUEST
Electric vs. Gas-Related R&D
($ Millions)

Research and Development Program	Gas-Related	Electric-Related*
Magnetic Fusion	N/A	483.10
Nuclear Fission	N/A	618.10
Fossil Energy	51.3	67.25
Conservation	15.9	5.20
Solar and Other Renewables	16.5	110.90
Electric Energy Systems	N/A	18.20
Energy Storage Systems	N/A	17.10
TOTAL	$ 83.7	$ 1,319.85

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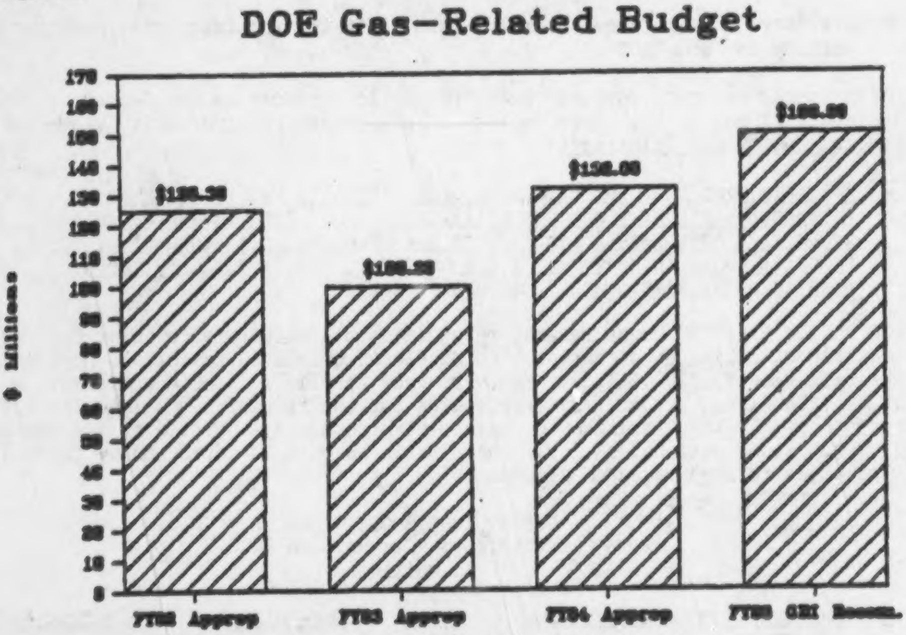
*This is a very conservative estimate of the request for electric-related research and development. No portion of the $746.1 million requested for General Sciences is included even though most of the energy-related benefits coming from this research will benefit the electric utility industry. Although most of the environment research and development funds are spent on R&D related to nuclear power, none of the $228.2 million request is included.

Regulatory constraints do create barriers that limit gas utilities' ability to fund research, but the DOE budget ignores these barriers.

5. Are the gas industry's FY 1985 budget recommendations consistent with federal policy and congressional direction?

The gas industry is recommending a DOE gas-related research budget in FY 1985 of $150 million. This level of funding is consistent with the budget approved by Congress for FY 1984. Also, the recommendations do not include large scale demonstration, near-term research, or commercialization activities; therefore, they are consistent with federal policy. Primary emphasis is on providing funds to continue activities already underway and previously approved by Congress.


DOE Gas-Related Budget

When you evaluate the gas industry's budget recommendations, you will find they are in the national interest, consistent with federal policy, and essentially identical to the actions taken by this subcommittee and Congress in approving the DOE FY 1984 budget.

At the end of my testimony is a table that provides details on the specific programmatic funding recommendations. However, Mr. Chairman, let me briefly mention five important long-term research recommendations that require federal support to continue joint DOE/gas industry projects.

RECOMMENDED GAS RESEARCH PROGRAMS

Consistent with the Administration's research policy, the gas industry has shifted its research program to focus its activities and funding priorities on near-term projects. Without an adequate and consistent federal long-term research program, the gas industry's concentration on near-term research will leave a large void in establishing the technology base required to develop cost-effective supplemental supplies of gas and more efficient appliances and processes that use gas.

FOSSIL ENERGY

($ Millions)	FY 1983 Appropriation	FY 1984 Appropriation	FY 1985 Gas Industry Recommendation
Surface Coal Gasification	$39	$36.79	$32.5

Despite the current glut of available gas and the impact of imbedded conservation measures, the ability of the gas industry to remain a long-term competitor in the energy market depends on the validation of the coal gasification option from the standpoints of both economics and technology. In order for coal gasification to have a significant impact in that time frame, we have to validate the needed economic and design data by the early 1990s.

Of particular importance is the development of advanced processes that can use high-sulfur Eastern coals and coal fines. Federal support in FY 1985 of $7 million is needed for further development of the Westinghouse process at Waltz Mill to continue PDU tests, cold-flow test facility operations, and laboratory research with an emphasis on environmental aspects.

Continued testing and operation of the pressurized ash agglomeration process at IGT is required to extend the technology to additional high-sulfur bituminous coals. A total of $6 million is recommended to continue these tests.

In addition, federal support is needed to continue basic research programs in improved catalysts, materials, components and instrumentation since significant improvements in the economies of coal gasification can result from improvements in downstream processing systems which currently comprise about one-third of the installed plant investment. A viable DOE program requires funding at levels consistent with the past two years' appropriations of $8.5 million to continue the timely development of these basic research elements of advanced coal conversion processes.

($ Millions)	FY 1983 Appropriation	FY 1984 Appropriation	FY 1985 Gas Industry Recommendation
Unconventional Natural Gas	$13.9	$13.5	$20

Why should Congress approve increased funds for long-term gas supply research in FY 1985? The reason is the lack of the required technology base. As the Administration states in the FY 1984 budget request, "There appears to be adequate U.S. reserves of natural gas for several decades if conventional and unconventional gas resources can be exploited. Unconventional gas will not realize its potential unless there is additional development of the scientific and engineering knowledge for associated extraction technologies." (Emphasis added).

Within the $20 million recommendation, the gas industry urges that $4.5 million be committed to research in Eastern Devonian shales; $7 million for Western tight sands; $5 million for methane from coal seams; and $3.5 million for advanced unconventional and environmental research.

($ Millions)	FY 1983 Appropriation	FY 1984 Appropriation	FY 1985 Gas Industry Recommendation
Fuel Cells			
Onsite	$ 4.0	$ 5.0	$ 6.0
Molten Carbonate	7.5	9.2	12.0
Advanced Concepts	2.5	2.0	2.0
	$14.0	$16.2	$20.0

A fuel cell is a cogeneration power plant that uses an electrochemical process to convert natural gas to hydrogen, react the hydrogen gas with oxygen from the air, and produce electricity, heat, and water. Installed onsite at a multifamily residential, commercial, or light industrial building, the fuel cell power plant can supply all of the electrical and heating requirements of the building.

The gas industry and GRI have made a major commitment in funding for onsite phosphoric acid fuel cell systems (from $11.3 million in 1982 to $19.6 million in both 1983 and 1984) to offset the loss of DOE funds for near-term research. The Gas Research Institute has now assumed the total cost of the joint DOE/GRI program to field test the 40 kW phosphoric acid fuel cell units.

The technology development program now being pursued under a joint effort with DOE and GRI is for the purpose of increasing reliability and lowering the costs of these onsite systems. On August 18, 1982, DOE initiated a four-year, $20 million program for this research with the manufacturer, United Technologies Corporation (UTC), that requires a DOE commitment of $6 million in FY 1985. The DOE work concentrates on the fuel cell stack; the fuel processing system, including catalyst research; the inverter; and specialty heat exchangers.

GRI has a parallel $6 million technology development program with UTC. Together, these joint research programs provide a solid technology base to enable the onsite fuel cell to meet the overall power plant cost, endurance, performance, and reliability goals. Also, continued long-term research by DOE is needed on advanced fuel cell concepts such as molten carbonate ($12 million) and solid oxides ($2 million).

CONSERVATION

($ Millions)	FY 1983 Appropriation	FY 1984 Appropriation	FY 1985 Gas Industry Recommendation
Gas Heat Pumps	$2.0	$3.0	$7.0

As ERAB has reported, the manufacturing sector is so diverse that individual companies cannot capture the benefits of conservation R&D; therefore, the federal research role becomes critical. Specific technology-based research is needed on an advanced gas prime mover and compressor necessary to produce a competitive heat pump for residential and commercial markets by 1990. To achieve this goal requires an expanded DOE program of $7 million in FY 1985.

Several attractive long-term technologies, specifically, free-piston Stirling engines, free-piston internal combustion engines, and double-effect absorption cycles, show a good probability of providing the reliable, long-life, high-efficiency operation required of heat pump systems. Multiple programs are needed due to the relatively early stage of development. Due to the high technical risk associated with long-term heat pump options, private industry cannot fund both the near-term and the long-term development costs.

To balance the recommended DOE program, GRI is planning to spend $5 million in both 1984 and 1985 for near-term research on these programs. With over 40 million homes now being heated with gas, a high priority must be placed on developing an advanced gas-fired heat pump that offers a 50 percent increase in efficiency over state-of-the-art gas furnaces.

SOLAR ENERGY

($ Millions)	FY 1983 Appropriation	FY 1984 Appropriation	FY 1985 Gas Industry Recommendation
Biomass (Gas-Related)	$4	$13	$20

The unique advantages of biomass make it an excellent candidate for many regions of the United States that lack conventional energy resources. To provide a model for developing biomass energy programs on a regional basis, GRI began a program with the University of Florida's Institute of Food and Agricultural Sciences in 1982. GRI has other related programs in the Northeast with the New York Gas Group and the New York State Energy Research and Development Authority and in the Southwest with Texas A&M University. All of these are cofunded efforts. We anticipate that many of the results are transferable to other parts of the country. DOE should expand the regional biomass concept by providing $4 million in the FY 1985 budget.

In terms of DOE-supported research, it should be directed in the next ten years to demonstrate at a reasonably large scale key elements of a regional biomass-to-methane system so that we have confidence in the attendant economics. This research should center on biotechnological advances that permit the manipulation of both the feedstock and the microorganisms used in the bioconversion process. Thus, using technically proven methods for cloning, infusion of genetic material into living cells, and conventional genetics, one can improve the characteristics of a plant for growth, for disease resistance, for the ability to fix nitrogen, and for a specific conversion process. One can simultaneously adapt the biological organisms of the conversion process to produce a more efficient system. With improved biomass feedstocks through bioengineering and other techniques, a cost-competitive energy system should begin to emerge.

The gas industry recommends that $12.5 million be used for biomass conversion, $1.5 million for waste conversion technology, and $2 million for research on biomass growth and harvesting.

SUMMARY AND RECOMMENDATIONS

A viable federal program consistent with Administration energy policy requires a budget in FY 1985 for a long-term gas research program of approximately $150 million. (See Table 1). It should be noted that this recommendation continues the programs approved by this subcommittee and Congress for gas-related research over the past two years and is approximately the same as appropriated by Congress just four months ago for the FY 1984 budget. (See Table 2).

Table 1
RECOMMENDED FY 1985 DOE GAS-RELATED RESEARCH BUDGET
($ Millions)

ADVANCED RESEARCH & TECHNOLOGY DEVELOPMENT	$ 13.5
Advanced gasification processes, fuel cells, materials and components, environmental analysis, instrumentation, coal utilization	
COAL GASIFICATION	32.5
Advanced concepts, pressurized fluidized bed ash agglomerating PDU, Great Plains, gasification mechanisms, coal ash studies	
UNDERGROUND COAL GASIFICATION	6.0
CRIP, Eastern coals, laboratory support	
UNCONVENTIONAL GAS	20.0
Tight sands (lenticular), Devonian shale, coal seam methane, advanced concepts	
FUEL CELLS	20.0
Onsite phosphoric acid technology development, molten carbonate, solid oxide	
EASTERN OIL SHALE GASIFICATION	2.0
CONSERVATION	22.0
Advanced gas heat pump, industrial cogeneration, desiccant systems, thermo-chemical recuperator	
LIQUID SPILL TEST FACILITY	3.0
BIOMASS	20.0
Growth, harvesting, conversion, waste conversion, regional programs	
GEOPRESSURED RESOURCES	11.0
Well data interpretation, coproduction, environmental	
TOTAL	$150.0

Table 2
CONGRESSIONAL APPROPRIATIONS FOR DOE GAS-RELATED RESEARCH
($ Millions)

	FY 1982	FY 1983	FY 1984	Gas Industry Recommendation FY 1985
FOSSIL ENERGY				
Advanced Research and Technology Development	$ 12.5	$ 7.4	$ 12.00	$ 13.5
Surface Coal Gasification	53.1	39.0	36.80	32.5
Underground Coal Gasification	8.3	6.0	6.00	6.0
Unconventional Gas Resources	8.7	13.9	13.50	20.0
Fuel Cells (Gas-Related)	5.6	14.0	16.20	20.0
Eastern Oil Shale Gasification				2.0
LNG Safety	6.3	3.5	3.25	3.0
SUBTOTAL	$ 94.5	$ 83.8	$ 87.75	$ 95.0
GEOPRESSURED METHANE	$ 17.3	$ 8.4	$ 7.00	$ 11.0
BIOMASS	$ 3.0	$ 4.0	$ 13.00	$ 20.0
CONSERVATION	$ 10.5	$ 4.0	$ 24.25	$ 22.0
TOTAL	$125.3	$100.2	$132.00	$150.0

Senator DOMENICI. Mr. Lee, Institute of Gas Technology, Washington, DC.

STATEMENT OF BERNARD S. LEE, PRESIDENT, INSTITUTE OF GAS TECHNOLOGY

Mr. LEE. Thank you very much, Mr. Chairman and Senator Ford, I appreciate the chance to express the views of IGT, a nonprofit organization in Chicago devoted to energy research and development.

We would like to first call for a mature energy policy that can provide long-term stability and security for energy in the United States. We feel that a mature energy policy must have three elements. First, there must be balance, balance between providing adequate energy supply and conserving energy resources through high efficency in utilization. Also balance within the energy supply sources, between nuclear and fossil.

In the past, we oversold the nuclear option to the point where fossil fuel, our most abundant indigenous resource, is grossly underutilized.

Second, a mature energy policy must preserve the environment. Acid rain has become a national issue. The fundamental way to solve acid rain is to first remove all the sulfur from the coal by gasification and gas cleanup, and then burn this clean fuel gas in advanced efficient combustion equipment.

Cogeneration, combined cycle or fuel cell power generation, substitute natural gas, chemical synthesis are all examples of combining coal gasification with efficient utilization. Stop-gap measures that do not eliminate the root causes of acid rain cannot succeed.

Third, a mature energy policy must provide continuity and sustained support for technology development. Excluding nuclear R&D funding, among 19 member nations of the International Energy Agency, America ranks 11th in the ratio of Government expenditures on energy R&D to gross domestic product and 16th in the ratio of R&D to primary energy demand.

Federal R&D funding today stresses long-range high-risk technologies carrying technology development only through the proof of concept stage, leaving the key process development and commercial demonstration stages to the private sector. There is no way that the private sector can do this, since these stages are the highest risk and most costly links in the overall development chain and require a timespan of 10 or more years.

While we wait for action, world energy supplies very likely will experience disruptions in less than 10 years and we as a nation will be caught unprepared. That risk is far greater and will cost the Nation far more than getting ourselves prepared through the implementation of a mature energy policy.

In light of this belief for 1985, therefore, I support the gas industry recommendations for $150 million in DOE appropriations for gas-related R&D.

Specifically, IGT highlights the following recommended areas. In coal gasification, $6 million to use an existing process research unit to extend the U-gas ash agglomeration gasification technique to high pressure on all types of U.S. coals. Extending the existing data base to 500 pounds per square inch pressure would maximize the overall efficiencies for combined cycle power generation and for the production of methanol, substitute natural gas, and chemicals.

IGT will bring significant contributions to this project by providing the use of its own 500-PSI process research unit and many other related equipment and facilities, and anticipates substantial funding by the Gas Research Institute with DOE to carry out this program.

Also in coal gasification, we recommend $10 million to develop a broad technology base including research on fluidization, gasification mechanisms, ash chemistry, gas cleanup and transfer of R&D results.

In oil shale gasification, $1 million to use existing facilities for converting shale fines and spent shale residues to nonleachable agglomerates for disposal.

In unconventional gas resources, $1 million for expanded measurements of rock properties in Devonian shale; $1.5 million to continue core analyses of western tight sands and $1 million on research on relaxation channels in coal seams to stimulate gas flow.

In geopressured methane, $5 million for definitive data collection from design wells, now operating, plus $1 million for expanded measurements of relative permeability and critical gas saturation.

In the biomass area, in the thermochemical conversion of biomass, $1 million to expand the data base of the renugas process in an existing pressurized process research unit.

In biological conversion of biomass, $1 million to study the first known inoculum which can gasify untreated woody biomass and $1 million to establish digester performance of giant brown kelp in a process research unit.

In converting wastes to fuel, $1 million for developing the two-phase digestion of municipal sewage sludge.

In fuel cells, $6 million to use existing facilities to expand the technology base of molten carbonate fuel cells through components evaluation, prototype endurance, contaminant effects, and electrolyte preparation.

In residential conservation, $1 million to develop an indoor air quality model; $2 million for an advanced gas/solar desicannt system for heating and cooling.

In industrial conservation, $3 million to develop thermochemical recuperation of high temperature waste heat and $2 million to develop an advanced cyclonic melter.

In hydrogen, $1 million for research and analysis of three promising hybrid cycles for thermochemical hydrogen production.

Finally, in addition to the gas industry recommendations, IGT recommends $4 million for thermal energy storage using composite molten salt, phase change materials.

Thank you, Mr. Chairman and members, for the opportunity to present my views. I would like to have my whole testimony included in the record please.

[The prepared statement of Mr. Lee follows:]

Statement by Bernard S. Lee, President
Institute of Gas Technology
Before the Senate Committee on Energy and Natural Resources
Subcommittee on Energy Research and Development
Hearing on FY1985 Authorization for the Department of Energy's
Fossil Energy Research and Development Program

March 12, 1984

Mr. Chairman and Members of the Subcommittee:

My name is Bernard S. Lee. I am President of IGT, a not-for-profit energy R&D organization in Chicago.

To meet its long-range energy needs and to preserve its environment, as well as that of its neighbors, America needs clean fuels which can be utilized at high efficiencies. We urgently need a mature energy policy that directs a balanced and sustained program to develop appropriate technologies to meet these needs. However, caught up in today's fast-paced microchip world in which innovations and obsolescence are measured in years rather than decades, we tend to apply the same criteria of quick turnovers to all national needs. That would be a mistake in the energy field. Energy policies must be established with long-term stability and security as top priority, paying special attention to the available and accessible energy sources, both in the U.S. and in specific geographic locations in the world.

From a world perspective, we should focus our attention on the steady growth in population, especially in developing countries. Nations that historically have existed on extremely low per capita energy consumption represent sources of explosive energy demand as they respond to internal pressures for even a modest improvement in living standards. It is pointless to expect those nations that have substantial energy resources and large populations to become significant energy exporters because their rising domestic demands will soon require all their supplies. For nations without substantial energy resources, growing populations will exert enormous pressure on the distribution of available world energy resources.

In the past, we oversold the nuclear option. Mesmerized by the promise of inexhaustible energy supply, we have disproportionately emphasized that option in terms of R&D expenditure in anticipation of unrealistically rapid deployment of nuclear installations. On the other hand, we undersold and neglected fossil fuel and renewable energy resources to the point where our largest indigenous energy resource is grossly under-utilized. The result is an unbalanced energy mix that will not lead to long-term stability.

We must have a maturity of energy policy for the United States which ensures the smooth flow of technology from the laboratory to commercial use and which realistically addresses future energy options. Although we fund large amounts of energy R&D, we fall behind many other countries which have adopted a policy of continuing, consistent and adequate funding of R&D to develop their indigenous energy resources. The International Energy Agency recently published a review of the 1982 national programs of R&D in the IEA countries. It is interesting to note that the United States is 9th in the ratio of 1982 government expenditures on energy R&D to gross domestic product, and 10th in the ratio of energy R&D to total primary energy demand. If nuclear R&D is excluded, the United States falls to 11th and 16th, respectively, of the 19 countries in the review.

I am deeply concerned by the complacency into which we have been lulled by the current energy situation. The issues on the public's mind are defense, toxic waste, entitlements, education, world peace, but not energy. Such misplaced priority is myopic. We know that fossil fuels will have to provide the bulk of our energy needs well into the 21st century, until renewable resources and, possibly, fusion energy can assume major roles. But, if we look at conventional oil and gas, warning signals are already evident. Domestic oil reserves peaked in the 1950's and have been declining ever since. The U.S. Geological Survey has warned that world oil resources may be even smaller than conservative estimates. Let us not forget that we still import large quantities of oil, and most energy analysts project even higher imports in future years. This has obvious implications for national policy on security and economic well-being.

The natural gas situation is similar. Proved reserves peaked in the mid-1960's and have dropped sharply since that time. Since 1967, yearly additions to reserves have been less than production for every year except 1981. Although indigenous natural gas supply is somewhat more favorable than oil supply, eventually we must turn to imports, development of unconventional gas sources, and synthetic gas to supplement natural gas supplies.

In this atmosphere of complacency, less support is also being given to efficient utilization technologies and applications, even though it has been amply demonstrated that conservation is capable of sharply reducing energy requirements and costs to the energy consumer. Renewable energy sources, too, are receiving less attention although these must become part of our future energy supplies.

A mature energy policy must preserve the environment. The acid rain issue is one of national and international concern. The expanded use of coal, our most abundant resource, must be anchored upon a technically sound and efficient base that complies with present and projected environmental regulations. The fundamental way to solve acid rain is first to totally remove sulfur and nitrogen from the coal by gasification and downstream processing and then to burn this clean fuel gas in advanced efficient combustion equipment. The more efficient the fuel utilization step, the less resource will be needed and the less pollutants emitted. Examples of coal gasification plus efficient utilization include cogeneration, combined cycle or fuel-cell power generation, industrial fuel gas, substitute natural gas, and chemical synthesis. Stop-gap measures to provide marginal improvements to alleviate immediate public pressures do not eliminate the root causes of acid rain, and therefore cannot succeed.

The current Federal R&D funding supports long-range, high-risk technologies. That alone is not enough. We need more than just basic research that enriches the scientific literature. Energy research is principally applied research; we must support the whole chain of development, from basic research to commercial applications. Yet, the current Department of Energy program limits technology development support only through the proof-of-concept step; the key process development and commercial demonstration steps are being left to private industry. However, these steps are the most costly and high-risk links in the chain. They require a time span of 10 or more years. In today's economic environment the private sector cannot undertake these risks. Unfortunately, the distinct possibility exists that world energy supplies will be interrupted at much shorter intervals than 10 years, and we as a nation will be caught unprepared. That risk is greater and will cost the nation more than the risk and cost of getting ourselves prepared through the implementation of a mature energy policy.

FY 85, I support the gas industry recommendations for $150 million in DOE appropriations for gas-related R&D, plus $4 million for thermal energy storage. Specific recommendations for programs are summarized in Attachment 1 and detailed in Attachment 2 of this testimony. I will highlight a few areas below.

Gasification

Of the $54 million gasification program recommended by the gas industry, in coal gasification IGT emphasizes two categories. Toward bringing advanced technology closer to commercial application, IGT recommends $6 million for a test program using the currently operating process research unit to extend the U-GAS ash agglomerating fluidized bed gasification technique to 500 psi on all types of U.S. coals in order to bring this advanced technology closer to commercial application. The work at IGT has shown that the ash agglomerating fluidized bed can achieve excellent conversion efficiency with many coals, even low-quality, high-ash, high-sulfur, and highly-caking coals. Extending the existing data base to 500 psi would maximize overall efficiencies for combined cycle power generation and for the production of methanol, substitute natural gas, and chemicals. We must expand our data base to include basic process understanding of the gasification kinetics, trace component formation, and ash characteristics as these are influenced by pressures in the 500 psi range. IGT will bring significant contributions to this project by providing the use of its own 500-psi 8-inch-diameter Process Research Unit and many other related equipment and facilities, and anticipates substantial funding by the Gas Research Institute with DOE to carry out this program.

Toward developing a broad technology base, $10 million is recommended comprising: $1 million on the investigation of the attrition and entrainment from fluidized-bed gasifiers in an existing Advanced Multi-purpose Research Reactor (AMRR); $0.5 million to study coal reaction mechanism using the ion impact technique; $0.5 million on gasification mechanism of sulfur, nitrogen and trace elements through using the isotopic labeling technique; $1 million on the behavior of coal ash during gasification; $0.5 million on determining the multi-component thermophysical properties of gasifier effluent streams; $1.5 million for testing composite sorbents in a bench-scale research unit for the removal of sulfides and halides; $1 million for bioprocessing of raw gasifier effluent to remove sulfur and produce methane; $2 million to determine the gasification characteristics of wet carbonized coals; $1 million for liquid-sealed lockhopper system; $1 million for compilation, evaluation, and correlation of coal gasification data useful to design engineers and scientists.

All current retorting technologies for oil shale discard potentially leachable residues and/or unretorted shale fines. IGT recommends $1 million to operate existing facilities for gasifying and agglomerating shale residues to recover the carbon value and to produce environmentally benign, non-leachable spent shale agglomerates for disposal.

Unconventional and Geopressured Resources

This $31 million program supported by the gas industry covers research in tight sands, Devonian shale, geopressured methane, deep source methane, gas hydrates, and methane from coal seams, all of which require intensive development before these tremendous energy resources can be utilized efficiently. In particular, we highlight a $1 million recommendation to expand the use of an existing computer-operated rock analysis laboratory (CORAL) to accurately determine the rock permeability and porosity properties of Devonian shale.

In support of the multi-well experiment in western tight sands, we recommend $1.5 million to analyze MWX cores and to augment core analysis in the Experimental Tight Rock Analysis (EXTRA) equipment to study two-phase flow in rock pores in order to allow comparison of actual production data with evolving computer models.

A $1 million program is recommended to use existing equipment to study the effect of relaxation channels in coal seams on permeability and compressive stress for several gassy coals.

In geopressured methane, $5 million is recommended for the collection of co-production data from existing design wells, and $1 million for accurately measuring compressibility, critical gas concentration, and relative permeability of brine to gas by upgrading laboratory equipment so that these data can be correlated with field data to permit predicting gas production from both geopressured and hydropressured wells.

Under advanced unconventional gas, $0.5 million is recommended for methane hydrates study to simulate its formation under natural conditions and to measure gas diffusion rate through the sediments.

Biomass

The $20 million program supported by the gas industry includes R&D in the thermochemical and biological conversion of biomass, the conversion of wastes, the growth and harvest of biomass and the support of regional programs. In biomass conversion, we highlight a $1 million recommendation to expand the data base of the RENUGAS process in an existing pressurized process research unit that converts biomass thermochemically to medium-Btu gas fuel or to synthesis gas, and $0.75 million to investigate the gasification behavior of biomass structural components and the catalytic reforming of heavy oils and tars produced in a biomass gasifier. Under biological conversion, we recommend $1 million to study the first known inoculum which can gasify untreated woody biomass to produce useful fuel gas, $1 million to establish digester performance of giant brown kelp in a process research unit, and $1 million to study microalgae and organisms for the production of fuels and chemicals.

In waste conversion, we recommend $1 million to construct and operate an on-site process research unit for the two-phase digestion of municipal sewage using a novel up-flow solids digester which has produced twice as much methane per unit of waste than heretofore possible, and $0.5 million to conduct tests on an existing landfill for producing gaseous fuels through a two-phase leachate recycle process.

Fuel Cells

The $20 million fuel cell progam supported by the gas industry includes first-generation phosphoric acid fuel cells, second-generation molten carbonate fuel cells, and other advanced concepts. Of these, the molten carbonate fuel cell has potentially the best combination of performance, efficiency, and cost to capture major portions of power generation and co-generation applications. This system lends itself to the use of coal through gasification or natural gas through internal reforming within the fuel cell.

A multi-year program with FY85 funding of $6 million is recommended to expand the technology base of the molten carbonate system by using existing facilities for evaluating components, testing prototype endurance, measuring effect of contaminants, and preparing electrolytes is a controlled environment.

Conservation

The $22 million program recommended by the gas industry covers building and community systems, industrial, transportation and hydrogen. We highlight under building and community systems a $1 million recommendation to develop an indoor air quality model based on existing comprehensive air infiltration model that would allow the evaluation of various alternative strategies for indoor air quality control. A $2 million program is recommended to develop an advanced desiccant system for residential environmental control with coefficient of performance up to 50 % higher than conventional air conditioning systems. $1 million is recommended to initiate a program to test and evaluate an advanced Hyperabsorption cycle heat pump. $0.5 million is recommended to develop an advanced analytical model for high-efficiency adiabatic diesel engines.

Under industrial conservation, we recommend several promising new approaches. The first is thermochemical recuperation of high-temperature heat from industrial furnaces into both combustion air and fuel, for which a $3 million program is recommended to develop a sub-scale facility to evaluate design parameters, conversion rates, and materials compatibility. The second is a $2 million program to develop a high-efficiency cyclonic melter which has broad applications in glass manufacture and mineral ore processing. In addition, $1 million program is recommended for development of an advanced combustor concept for industiral applications in which the heat exchange surface is located directly in the combustion zone, and $0.5 million is recommended to develop an advanced firetube melter for aluminum reovery.

Hydrogen research through thermochemical or thermoelectrochemical cycles using nuclear fusion, fission or solar energy as a high temperature heat source is recommended in a $3 million program, of which $1 million is assigned to evaluating three promising hybrid hydrogen cycles based on copper, zinc, and cadmium chemistry.

Thermal and Mechanical Energy Storage

Energy stored as heat at elevated temperature, or thermal energy storage (TES), can later be used for on-site commercial or industrial applications. One thermochemical method to accomplish TES is the use of melted salts or salt mixtures.

IGT recommends, within the Thermal and Mechanical Energy Storage category, $4 million for the intensified development of thermal energy storage using composite molten-salt phase-change materials.

Thank you for the opportunity to present my views. I will be happy to answer your questions.

ATTACHMENT 1
TO STATEMENT BY BERNARD S. LEE
March 12, 1984

For FY'85, IGT specifically recommends:

- $6 million for a test program using the pressurized U-GAS ash agglomeration process research unit
- $10 million for coal gasification technology base research
- $1 million for converting spent shale residues to non-leachable agglomerates for disposal
- $1 million for expanded Devonian shale rock property measurements
- $1.5 million to continue augmented core analyses of Western tight sands to study two-phase flow in rock pores
- $1 million for research on relaxation channels in coal seams to stimulate gas flow
- $5 million for the collection of co-production data from geopressured design wells
- $1 million for expanded measurements of relative permeabilities and critical gas saturation in geopressured formations
- $0.5 million for study of methane hydrates formation and behavior under natural conditions
- $1 million to expand the data base of the RENUGAS process
- $0.25 million to investigate the gasification behavior of biomass structural components
- $0.5 million for research on the catalytic reforming of biomass gasifier liquid products
- $1 million for biological gasification of woody biomass without pretreatment
- $1 million for a process research unit to convert giant brown kelp to fuels
- $0.75 million to study microalgae and microorganisms for producing fuels from biomass
- $1 million for the two-phase biological digestion of municipal sewage sludge
- $0.5 million for LANFILGAS process development
- $6 million for technology base expansion of the molten carbonate fuel cell
- $1 million to develop an indoor air quality model
- $2 million for an advanced gas/solar desiccant system for residential heating and cooling
- $1 million for the development of Hyperabsorption heat pump cycle
- $0.5 million for diesel engine performance improvement
- $3 million for development of a novel thermochemical recuperative system
- $2 million for development of an advanced cyclonic melter
- $1 million for a novel surface combustor development
- $0.5 million for an advanced firetube aluminum melter development
- $1 million for hybrid hydrogen cycles evaluation
- $4 million for thermal energy storage using composite molten-salt phase-change materials

GASIFICATION

Coal

IGT recommends $6 million for a test program using the currently operating process research unit to extend the U-GAS ash agglomerating fluidized bed gasification technique to 500 psi on all types of U.S. coals.

IGT also recommends $10 million to carry out technology base research comprising: $1 million on the investigation of the attrition and entrainment from fluidized-bed gasifiers in an existing Advanced Multi-purpose Research Reactor (AMRR); $0.5 million to study coal reaction mechanism using the ion impact technique; $0.5 million on gasification mechanism of sulfur, nitrogen, and trace elements through using the isotopic labeling technique; $1 million on the behavior of coal ash during gasification; $0.5 million on determining the multi-component thermophysical properties of gasifier effluent streams; $1.5 million for testing composite sorbents in a bench-scale research unit for the removal of sulfides and halides; $1 million for bioprocessing of raw gasifier effluent to remove sulfur and produce methane; $2 million to determine the gasification characteristics of wet carbonized coals; $1 million for liquid-sealed lockhopper system; $1 million for compilation, evaluation, and correlation of coal gasification data useful to design engineers and scientists.

Shale

All current retorting technologies for oil shale discard unretorted shale fines and potentially leachable residues that represent environmental problems. These materials contain carbon which amounts to as much as 50% of the total energy available in the shale as mined. IGT recommends $1 million to operate existing gasification equipment to develop the ash agglomerating fluidized-bed technique for gasifying and recovering the carbon in shale discards and producing environmentally benign, non-leachable spent shale agglomerates for disposal.

UNCONVENTIONAL AND GEOPRESSURED RESOURCES

- Accurate determination of the Devonian shale rock properties is critical to the capability of predicting gas production from this resource. IGT's computer operated rock analysis laboratory (CORAL) provides both permeability and porosity measurements representative of in-situ conditions. IGT recommends $1 million to expand the CORAL facility and the Devonian shale property measurements.

- The current work on the western tight sands multi-well experiment (MWX) core sand provided the first basis for comparing post-hydraulic fracture production with predictions based on reservoir rock properties. IGT recommends $1.5 million to continue analysis of the MWX cores in CORAL and to augment core analyses in the experimental tight rock analysis (EXTRA) equipment used to study two-phase flow in rock pores so that existing predictive computer models using the measured physical property data could be compared with actual production data.

- IGT's continuing research on coal seam methane production has led to the first understanding of how hydraulic fracturing works in these formations and why success has been limited to date. IGT recommends $1 million to study the effect of relaxation channels on gas production and the dependence of permeability on compressive stress for several gassy coals by adapting existing laboratory equipment.

- In the geopressured methane area, the ability to predict gas content and long-term co-production of gas and hot brine requires extensive testing to accumulate accurate experimental information needed for data correlation. IGT recommends $5 million for the collection of definitive data from the existing design wells and $1 million for adapting existing laboratory equipment to measure critical gas saturation and relative permeabilities to gas and brine.

- Present knowledge, though very limited, indicates the potential for extensive deposits of methane hydrates in the Arctic deep ocean sediments. IGT recommends $0.5 million for the laboratory investigation of the formation and behavior of methane hydrates under natural conditions.

BIOMASS

- IGT recommends $1 million to determine reactant requirements, product specification, environmental impact, and overall economics of the RENUGAS process in an existing pressurized fluidized-bed process research unit built with DOE funds. The RENUGAS process converts biomass and waste thermochemically to fuel gas or synthesis gas.
- $0.25 million to investigate the gasification behavior of biomass structural components, i.e., cellulose, hemicellulose and lignin.
- $0.5 million to investigate the catalytic reforming of heavy oil and tars from biomass gasifiers into lighter and more useable hydrocarbons.
- $1 million to establish the potential of an important break-through, the first known inoculum which can gasify woody biomass without prior treatment.
- $1 million to design, construct and operate a process research unit to determine digester performance and perform process evaluation for the conversion of giant brown kelp into fuels and chemicals.
- $0.5 million for bioassay screening and bench-scale digestion tests to determine the methane production potential of a wide variety of microalgae species.
- $0.5 million for the co-production of fuels and chemicals for biomass using biological organisms.
- In waste conversion, IGT has achieved in its two-phase digestion laboratory studies twice the production of methane per unit of waste compared to single-phase digestion technologies. IGT recommends $1 million to construct and operate an on-site process research unit for the two-phase digestion of municipal sewage sludge using a novel upflow solids digester.
- $0.5 million for testing the LANFILGAS process for biologically digesting landfills through a two-phase, leachate recycle approach

FUEL CELL

In the molten carbonate fuel cell area, IGT specifically recommends $6 million to initiate a multi-year program on technology base expansion which focuses on using existing facilities for evaluating components, testing prototype endurance, measuring effects of contaminants, and preparing electrolytes in a controlled environment. The MCFC system has potentially the best combination of performance, efficiency, and cost for applications in power generation and co-generation.

CONSERVATION

- IGT recommends $1 million to develop an indoor air quality model based on its existing comprehensive air infiltration model and to evaluate various alternative strategies for indoor air quality control.

- $2 million to initiate a program to build and test in the laboratory the H-COP concept for residential heating and cooling. This is an advanced high-efficiency concept based on a gas-fired, open-cycle, solid-desiccant system that can be coupled with a solar energy source.

- $1 million to initiate a program to build and operate the combined-cycle heat pump test unit based on IGT's Hyperabsorption cycle.

- In industrial conservation, IGT recommends a $3 million program to develop a proof-of-concept facility for a thermochemical recuperative system to evaluate design parameters, conversion rates, and materials compatibility. Such a system could double the waste heat recovered from high-temperature industrial furnaces.

- $0.5 million to develop an advanced analytical model for high-efficiency adiabatic diesel engines.

- A cyclonic melter or furnace with twice the efficiency of today's most advanced industrial furnace has wide application in the glass melting and mineral ore processing industries. IGT recommends $2 million to perform bench-scale development work of the cyclonic melter to lead to the design of the prototype unit.

- $1 million to develop a novel advanced combustor which has the heat exchange surfaces located directly in the combustion zone of the burner.

- $0.5 million to initiate investigations of an advanced firetube aluminum melter

- $1 million to experimentally evaluate the kinetics, product purification, process/energy source interface and engineering optimization of three promising hybrid cycles for hydrogen production via the thermochemical splitting of water.

THERMAL AND MECHANICAL ENERGY STORAGE

- IGT recommends $4 million for the intensified development of thermal energy storage using composite molten-salt phase-change materials. Proof-of-concept testing is now underway for industrial applications of this technology which has wide application from thermal installations to utility load management.

ATTACHMENT 2
TO STATEMENT BY BERNARD S. LEE
March 12, 1984

GASIFICATION

Coal Gasification

Pressurized Ash Agglomeration Process Research Unit

The ash agglomerating fluidized bed permits excellent conversion efficiency with any type of coal, even low quality, high-ash, high-sulfur, highly-caking coals, as evidenced in the U-GAS process for producing medium-Btu industrial fuel gas. It is necessary to extend the existing data base to 500 psig — the pressure level required for combined cycle power generation and for the production of methanol, SNG, and chemicals. IGT is now operating its own 500-psi, 8-inch diameter Process Research Unit (PRU) to obtain data on the effects of pressure, temperature, and carbon concentration on the ash agglomeration qualities of an Illinois basin coal. Further experimentation is needed to extend high-pressure ash agglomeration to lignites, subbituminous, and other high-sulfur bituminous coals. We must expand our data base to include basic process understanding of the gasification kinetics, trace component formation, and ash characteristics as these are influenced by pressures in the 500-psi range. IGT will bring significant contributions to this project by providing the use of its unique PRU and many other related equipment and facilities, and anticipates substantial funding by the Gas Research Institute with DOE to carry out this program.

IGT recommends $6 million to continue operations on the high-pressure 8-inch diameter PRU so that the ash U-GAS agglomerating fluidized bed gasification technique can be extended to 500 psi for all types of U.S. coals.

Technology Base Research

o The production of fines by both chemical and mechanical action in a fluidized bed is a major process factor in the development of this technology. Fines blown from the bed must be collected and recycled several times to achieve high carbon conversions. The presence of fines in the product gas creates mechanical problems in downstream processes, especially in combined cycle power generation. Detailed data are necessary to understand and minimize the cause of fines productions under realistic operating conditions.

IGT recommends $1 million for the operation of any existing high-pressure, high-temperature fluidized bed Advanced Multipurpose Research Reactor (AMRR) to obtain specific data on the chemical and mechanical causes of fines production in fluidized bed gasifiers.

o The reactions of ionized gas with coal can produce intermediate chemical species which, if identified, will provide valuable data on the kinetic mechanisms occurring during the initial stages of gasification at the very surface of the coal. Understanding these fundamental reactions can increase the efficiency and decrease the cost of coal gasification processes. Similar techniques are being used in the biomedical field to determine the surface chemistry and structure of vitamins and carbohydrates.

IGT recommends $0.5 million to extend the ion impact technique for determining the chemical structure of intermediate kinetic species to coal gasification using existing high resolution analytical equipment.

o Further advances in our surface coal gasification technology can be realized through a more fundamental understanding of the mechanisms by which coal is converted to gaseous and liquid end products. Isotopes of the heteroatoms, sulfur, nitrogen, and trace element contaminants, can be used as labels to trace the fate of the key structural elements in coals as they undergo fragmentation and substitution reactions. Such research will also provide the basic data needed to economically and efficiently process these contaminants in an environmentally acceptable manner.

IGT recommends $0.5 million to extend isotopic labeling technique to the major heteratoms of sulfur, nitrogen, and oxygen in coal to better control the conversion mechanism of these potentially contaminating elements in future coal gasification technologies.

o The understanding of ash behavior and chemistry during gasification is essential to the design of ash agglomerating gasifiers. It is, therefore, necessary to obtain data establishing the effects of temperature, pressure, size, and composition on the kinetics and mechanics of coal ash particle agglomeration in the 1800°-2500°F temperature range.

IGT recommends $1 million to continue the fundamental research on coal ash behavior using an existing novel needle penetrometer and high-pressure hot-stage microscope to obtain data in the ash agglomeration temperature regime.

o Generic physical property data are needed to allow for proper design of coal gasifier raw product handling systems. In the rapid cool-down (or quench) step, some of the components such as hydrogen sulfide and ammonia, in the product gas stream condense. Some of the products enter the waste water treatment system. The lack of data for predicting the condensing behavior of these compounds leads to costly ove-design of the quench and environmental control system.

IGT recommends $0.5 million for determining the multicomponent thermophysical properties of gasifier effluent streams in existing laboratory equipment capable of analyzing the concurrent condensing behavior of hydrogen sulfide and ammonia.

o Past research at IGT has identified several promising sorbents for the removal of chemical contaminants from coal-derived fuel gases at elevated temperatures and pressures. These composited mixed metal oxide sorbents can remove sulfides, mercaptans and halides. The contaminants adversely affect the performance of combined-cycle power turbines, catalytic reactors, and fuel cells; hence, they must be removed for the successful application of coal gasification technology to these areas. Further research is needed to validate the long term performance of these composite sorbents in a continuous laboratory research unit.

IGT recommends $1.5 million for the construction and operation of a high-temperature, high-pressure bench-scale research unit to continue the development of composite sorbents for removing sulfide and halide contaminants from coal gasifier effluent streams.

o Basic research is under way on a novel biological technique for upgrading raw gasifier effluent gases to sulfur-free fuel gas. A two-step biological process first converts synthesis gas to methane and then removes sulfur contaminants. This process operates at low pressures and temperatures and eliminates the need for costly hot pressurized catalytic shift and methanation reactors. Further laboratory research is necessary to determine preferred culture concentrations and optimize digester size and gas throughput rates.

IGT recommends $1 million to continue the laboratory research of a novel two-step biological technique for upgrading raw gasifier effluent gases.

o Wet carbonization is an effective method for beneficiating low-rank coals. The use of beneficiated coals can significantly improve the efficiency of coal gasification. To determine the gasification reactivity characteristics of the carbonized coal, laboratory data must be validated with a bench-scale experimental test unit capable of gasifying the prepared coals over a wide range of operating conditions.

IGT recommends $2 million to determine the gasification characteristics of wet-carbonized coals produced from an existing wet-carbonization process research unit.

o The feeding of solids into and the discharging of residues from pressurized coal gas plant reactors continues to be a major capital and operating cost. Conventional pneumatic lockhopper systems utilize product gas or inert gas as the pressurizing medium, resulting in high gas compression costs, loss of valuable product gas and mechanical valve sealing problems. Use of liquid (non-compressible fluid) filled hoppers has the potential to eliminate most of the problems associated with the pneumatic lockhopper. Particulate solids in the feed and discharge hopper displace a non-compressible fluid (usually water). A special patented dewatering screw feeder delivers drained solids from the top feed hopper to the reactor while a similar device delivers drained residue from the reactor. It is critical to deliver drained solids with very low liquid content to the gasifier. Previous experimental work with large lumps has demonstrated the feasibility of the process. Additional experimental work on the range of allowable particle sizes, the drainability of the particles and the capacity limits of the system must be done to fully develop the concept.

IGT recommends $1 million to examine the range of applicability of the liquid-sealed lockhopper.

o DOE has invested several years of effort in accumulating much basic data on the thermodynamic and physical properties of a myriad of hydrocarbon compounds. These basic data are needed as input to computerized design packages that allow rapid calculation of process stream composition, energy and material balances, and reactor sizes. A need exists to collect, categorize, and evaluate this data and be put into a format that will be readily compatible with state-of-the-art computerized design calculation software. Additional basic data requirements would be easily identifiable as a result of this effort, which should be continued for several years.

IGT recommends that initial funding for this program be at a $1 million per year level of effort.

Shale Gasification

Current retorting technologies for U.S. oil shale discard unretorted fines and potentially leachable residues that present environmental problems. These materials contain carbon which amounts to as much as 50% of the total energy available in the shale as mined. These shale materials can be gasified in an ash-agglomerating, fluidized bed to produce additional gaseous energy while simultaneously immobilizing potentially leachable material in the form of environmentally benign, non-leachable spent shale agglomerates.

IGT recommends $1 million to operate existing gasification equipment to develop the ash-agglomerating, fluidized bed technique for gasifying and recovering the carbon in shale discards and producing environmentally benign, non-leachable spent shale agglomerates for disposal.

UNCONVENTIONAL AND GEOPRESSURED RESOURCES

Eastern Devonian Shale

The key to the reliable assessment of this potential energy supply lies in the predictive capability which requires accurate determination of the rock properties. The work now being conducted on Devonian shale rock permeability and porosity in the IGT Computer-Operated Rock Analysis Laboratory (CORAL) indicates that each sample may have to be in the measurement apparatus for several weeks before quantitative measurements representative of in-situ reservoir rock can be obtained. Timely progress in this vital area dictates that additional experimental equipment be constructed to expand the capability of the existing CORAL laboratory.

IGT recommends $1 million to expand the CORAL laboratory and to provide operating funds for the continuation of these rock property measurements.

Western Tight Sands

The current work on the Multi-well Experiment (MWX) core samples has provided a deeper understanding of the characteristics of gas reservoirs and adjacent strata. The stimulation and production tests planned for 1984 will provide the first basis for comparing post-hydraulic fracture production with predictions based on reservoir rock properties. The continuing program for research in tight sands should emphasize long-range research on the measurements of reservoir rock properties as well as refinements in computer simulation techniques needed to improve the predictive capabilities for estimation of reserves and production.

IGT recommends $1.5 million to examination of the MWX cores in CORAL and to augment core analyses in the Experimental Tight Rock Analysis (EXTRA) equipment so that existing predictive computer models using the measured physical property data can be compared with actual production data.

Methane from Unmineable and Interbedded Coal Seams

Continuing IGT research on coal bed methane production has led to the first understanding of how hydraulic fracturing works in these formations and why success has been limited to date. Because of the physical nature of coal beds, hydraulic fracturing increases compressive stress adjacent to the fracturing formations, thus reducing the permeability. Continued research is needed to test the effect of compressive stress on permeability and to investigate various means of producing long "relaxation" channels in the coal bed.

IGT recommends $1 million to study the effect of relaxation channels on gas production and the dependence of permeability on compressive stress for several gassy coals by adapting existing laboratory equipment.

Geopressured Methane

Production of hydrocarbons must exceed solubility in reservoir brine if production economics are to be favorable for the pressures and temperatures of wells tested to date. If the brine initially produced is not saturated at reservoir pressure and temperature, it is unlikely that greater hydrocarbon production will occur from that reservoir. It is therefore recommended that sampling, sample analysis, and test instrumentation for existing design wells be upgraded as appropriate to resolve existing discrepancies in well test results and laboratory studies of hydrocarbon solubility.

Funds should be appropriated for testing of the higher temperature, higher pressure Willis Hulin No. 1 well. In addition, the scope of research on energy production with high brine rates should be expanded to include hydropressured, as well as geopressured, reservoirs.

IGT recommends $5 million for the collection of co-production data from existing design wells and $1 million for adapting existing laboratory equipment for measuring critical gas saturation and relative permeabilities to gas and brine with the accuracy required to predict gas production from both geopressured and hydropressured wells.

Methane Hydrates

Present knowledge, though very limited, indicates the potential for extensive deposits of methane hydrates in the Arctic and deep ocean sediments. This hydrate may in some circumstances also serve as a trap for gaseous methane. It is important to assess the location, magnitude and possible economic recovery of these resources. To this end a comprehensive multi-year research program, both laboratory and field, should be undertaken.

IGT recommends $0.5 million for the laboratory investigation of the formation and behavior of methane hydrates under simulated natural conditions. By adapting existing high pressure rock analysis equipment, gas hydrates formation can be simulated in ice and in their sediments. This increased understanding combined with diffusion rate measurements of the gas released from the hydrate would lead to characterization of this reservoir and the tailoring of tools to recover this energy source economically.

BIOMASS

Biomass Conversion

o Pressurized steam-oxygen or steam-air thermal gasification is a very attractive route to produce useful energy from biomass. The existing IGT RENUGAS Process Research Unit (PRU) built with DOE funds was specifically designed to obtain accurate scale-up data on the thermal conversion of biomass via pressurized fluid-bed gasification to medium-Btu fuel gas or synthesis gas for the production of substitute natural gas, methanol, or other transportation fuels. The PRU operates adiabatically and is of sufficient size (12-in. I.D.) that gasification data can be accurately scaled to commercial size applications.

IGT recommends $1 million to determine reactant requirements, product specification, environmental impact and overall economics of this approach to biomass energy conversion using the high-pressure, adiabatic, steam-oxygen RENUGAS PRU.

o Woody biomass is considered to be the most appropriate feedstock for the production of substitute fuels or synthesis gas by thermal gasification. Most of the wood species have similar elemental composition, when expressed on a moisture and mineral matter free basis, but they differ in their structural composition, i.e., cellulose, hemicellulose, and lignin contents. Since nearly 80% of the biomass undergoes rapid devolatilization during thermal gasification, the distribution of these structural components determine the product gas composition. For example, lignins contribute to the production of direct methane while cellulose produces carbon monoxide and hydrogen. Bench-scale experiments are needed in existing laminar flow and thermobalance reactors to develop consistent solvent extraction methods to isolate the biomass structural components in different woody biomass species and to determine their devolatilization and char gasification behavior. Correlating the distributions of biomass structural composition and the devolatilized products would form the basis for recommending the most desirable feedstocks for medium-Btu or synthesis gas production. This information would also direct genetic engineers in the cultivation of new biomass species optimized for thermal gasification.

IGT recommends $0.25 million to investigate the gasification behavior of biomass structural components.

o Biomass gasifiers, the moving-bed gasifiers in particular, produce heavy oils and creosote tars which can cause mechanical operability problems as well as requiring special processing equipment to assure environmental acceptability of the process effluent. Biomass gasification processes would benefit from elimination of these heavy oil and tar products. Bench-scale experiments are needed to determine the effect of inexpensive and disposable alkaline metal-oxide catalysts on the decomposition of heavy oils and creosote tars into simpler hydrocarbon species. The bench-scale data would then be analyzed to identify effective catalysts and to develop process concepts for heavy oil and tar decomposition.

IGT recommends $0.5 million to investigate the catalytic conversion of biomass gasifier liquid products.

o IGT has developed the first known inoculum that can convert untreated woody biomass to methane by anaerobic digestion. This method of gasification could have the advantage of producing a high quality gas with few contaminants at a low cost. Woody biomass has a major advantage over other renewable energy forms in that it can be grown with high yields at a variety of locations in the U.S. Research should include a screening of a variety of different woody species to determine their biodegradability, gasification potential, and reactivity as a function of growth and harvest conditions. Laboratory and bench-scale studies should be conducted to determine the best reactor type and operating conditions for maximum conversion of wood to methane. This research will provide data needed for process design, scale-up, and economic assessment.

IGT recommends $1 million to genetically improve the IGT wood digestion inoculum, determine conditions optimum for its growth and metabolism, and develop a process to convert woody biomass to usable fuel gas.

o Giant brown kelp, grown in California coastal waters, has been shown to be highly amenable to anaerobic digestion for methane production. The species has demonstrated high methane yields and production rates during very stable fermentation in an upflow solids reactor. These laboratory studies need to be supported by testing in a continuous bench-scale process research unit to validate digester performance and evaluate equipment for continuous feed preparation and effluent handling. The final process scheme, selected as a result of these studies, will be operated as an integrated unit to permit optimization of the final conceptual process design and to provide a data base for detailed system analysis.

IGT recommends $1 million to design, construct and operate a process research unit to determine digester performance and perform process evaluations.

o Microalgae have a high potential for energy and chemical applications because they exhibit rapid growth, high yields, and most species are not needed for other applications in the U.S. A screening program is recommended to collect, analyze and evaluate the suitability of various microalgal species for conversion to methane. Ongoing growth programs should be identified as a source of microalgae with well-documented genetic and environmental data. The biogasification potential of these feeds should be examined using established anaerobic bioassay techniques to assess biodegradability and methane production to select a prototype species for further study. Process variables with the potential to influence methane production rates and yields should then be evaluated to develop a data base for bench-scale digester operation.

IGT recommends $0.5 million for bioassay screening and bench-scale digestion tests to determine the methane production potential of a wide variety of microalgae species.

o During the process of decomposing biomass or organic waste, microorganisms produce various products that may be useful as fuel or industrial chemicals. Two such well-known fuels are methane and ethanol. Based on work conducted at IGT, biotechnology research has demonstrated that production of other chemicals such as hydrogen, acetic acid, acetone, butanol, methanol, and processed lignin is possible. The production of these chemicals via microbial conversion of biomass and waste represents a potentially economic and environmentally desirable option. A balanced basic and applied research program is needed to develop the organisms and optimize the growth conditions for production of these fuels or chemicals.

IGT recommends $0.5 million to conduct basic and applied research on the biological coproduction of fuels and chemicals from biomass.

Waste Conversion

o Current IGT research in its two-phase digestion process with municipal sewage sludge has produced 7.5 cubic feet of methane for every pound of dry organic matter processed, about twice what current single-phase digestion technologies can produce. A novel upflow solids digester is showing high promise as the digester type to be used for processing sludge. The next logical step is to construct and operate a continuous, adiabatic larger scale process research unit. Continuous on-site testing is necessary to prove the upflow reactor concept.

IGT recommends $1 million to construct and operate an on-site PRU to provide proof-of-concept data for the two-phase digestion process for municipal sewage sludge.

o Two-phase biological digestion can also be used to recover energy from solid waste landfills. IGT's LANFILGAS process uses controlled recirculation of an aqueous phase bacterial culture to stabilize the organic waste within the landfill and to produce methane by two-phase digestion of leached organics in the recirculating liquid culture. The process can be applied to large as well as small landfills. Small-scale laboratory data indicate the technical feasibility of the concept. Further data are needed at the bench-scale level to study the effects of culture recirculation rate, digester temperatures, and hydraulic and solids retention times in the acid-phase and methane-phase digesters.

IGT recommends $0.5 million to conduct two-phase, leachate recycle, proof-of-concept tests on an existing landfill.

FUEL CELLS

Molten Carbonate Fuel Cells

The molten carbonate fuel cell (MCFC) operating on gasified coal, reformed hydrocarbons or internally reformed methane can provide an efficient, low-cost solution to our future needs in power generation. Not only can it serve the central station and dispersed power sectors but, using natural gas, can yield a high efficiency cogeneration system for industry. IGT is preeminent in MCFC technology and maintains laboratory and development facilities for fuel cells and the related technologies of gasification and gas clean-up systems.

IGT proposes a multi-year program, and recommends the following $6 million program in FY'85 for technology base expansion:

o Utilize existing facilities and capabilities to develop, test and evaluate innovative fuel cell components such as the electrolyte, anode, reforming catalyst for internal reforming cells, and the cathode and bipolar plate; endurance testing of bench-scale cells and stacks of cells; and carbonate management schemes and stack design. Using existing DOE facilities for testing prototype endurance, for measuring the effect of contaminants on cell performance, and for electrolyte preparation in a controlled environment would be cost effective and would provide impartial dissemination of information on cell life and performance directly to all potential manufacturers.

o Basic electrochemistry and accompanying support studies that seek improved cell performance and endurance.

o Systems analysis of power plant designs and configurations, including performance modelling, gasifier selection, feasibility of anode gas recycle and establishment of fuel tolerance.

CONSERVATION

Building and Community Systems

o Following the enactment of the Source Emission Standards and National Ambient Air Quality Standards covering outdoor air contaminants in the early 1970's, attention has now been directed toward indoor air quality and its relation to indoor air pollution epidemiology. It is generally agreed that indoor air quality is a complex function not only of outdoor pollutant concentrations, building permeability, internal generation, and meteorological conditions, but also of contaminant control measures, control equipment design and, more recently, energy conservation measures. By far, the most important subroutine required for an integrated air quality model is a model for air infiltration.

IGT recommends $1 million to develop an indoor air quality model based on IGT's existing comprehensive air infiltration model and to evaluate various alternative strategies for indoor air quality control including air-to-air heat exchangers, spot ventilators, air cleaning devices.

o An advanced gas/solar or gas-only desiccant system, the H-COP, was developed by IGT for residential heating and cooling. This design features a 95% efficient heat exchanger wheels and advanced reactivation design. The calculated seasonal "energy efficiency ratio" (EER) is twice that of commercially available air conditioning systems, and the projected cooling performance exceeds that of other systems now under development by more than 50%.

IGT recommends $2 million to build and test laboratory scale H-COP concept in a configuration designed for residential use, including a gas-only and gas/solar firing. This unit would allow for improved desiccant and desiccant support research, advanced burner development, and advanced control system development.

o Because of less than adequate heat actuated heat pump performance by well-known mechanical power cycles (Rankine, Stirling, Brayton, Otto) and single-effect absorption concepts in providing efficient comfort control, emphasis has shifted to combined-cycle mechanical heat pumps (Vuileumier, Ericsson-Ericsson, or Stirling-Stirling) and high efficiency absorption cycles (such as IGT's Hyperabsorption Cycle) because of the promise of achieving nearly 90% of their theoretical efficiency limits.

IGT recommends $1 million to initiate a program to design, engineer, fabricate, and evaluate a 3-ton combined-cycle heat pump test unit based on IGT's Hyperabsorption Cycle.

o Recently, developments in small, stationary automotive prime movers have been directed toward improved fuel economy, decreased emissions, and improvements in operating characteristics such as dynamic response, proper ratio of maximum to nominal torque. For diesel engines, the combination of a decrease in heat loss and associated heat recovery offers better improvement potential for adiabatic diesel engines than improvement of the combustion process within the cylinder,according to assessments at IGT with screw compressors and expanders.

IGT recommends $0.5 million to complete the development of an analytical model to evaluate the performance of screw compressors and expanders as they relate to diesel engines and to study the influence of design changes on system performance. The model development will include dynamic effects and provide insight into the feasibility of manufacturing processes employing advanced ceramic or composite materials.

Industrial

o A novel thermochemical recuperative system (TCRS) should be developed that can greatly increase waste-heat recovery in high-temperature industrial furnaces, such as in the fiberglass and steel industries. State-of-the-art metallic recuperators are limited to about 1500°F in air preheat. Work is underway to develop ceramic heat exchangers to increase this to 2000°F. The TCRS, however, uses no exotic ceramics. Instead, it recuperates the high-temperature waste-heat into both the combustion air and fuel via the thermochemical conversion of natural gas with steam. The resulting synthesis gas mixtures, when combusted with air preheated by state-of-the-art technology, is equivalent to an air preheat of 2600°-2900°F.

The TCRS offers waste-heat recovery efficiencies exceeding 70% as compared with only 30% to 40% for conventional recuperation, provides fuel savings of up to 30% above that achieved by conventional recuperation, increases furnace production rate and improves product quality, and reduces NO_x emmission per unit of product.

IGT recommends $3 million to construct and test a proof-of-concept facility of the TCRS to evaluate design parameters, conversion rates, and materials compatibility. The results will lead to a test program of a large scale prototype at an industrial site.

o A cyclonic melter or furnace with an efficiency of 80%, contrasted with the 40-45% efficiency of today's most advanced industrial furnaces, is the goal of this program. Features of the proposed furnace are: extremely high melting intensity, and separation of combustion products from melt.

The melter would have wide industrial applications in glass melting, phosphate rock melting, chromium ore melting, mineral wool production, fiberglass manufacture, and vitreous enamel frit production.

IGT recommends $2 million to perform bench-scale development work of the high efficiency cyclonic melter, leading to the design of a prototype unit.

o An advanced combustor concept, particularly applicable to package boilers and process heaters, has been developed which locates the heat exchange surfaces directly in the combustion zone. Such a combustor would reduce the peak flame temperature substantially, thereby significantly reducing NO_x formation, which is a principal pollutant in the flue- gas emissions. Furthermore, such a combustor would improve the heat-transfer rates and efficiency, and reduce the combustor size, all of which would mean substantial reduction in capital and operating costs.

IGT recommends $1 million for research and development in heat exchange materials, flame support surface, combustion stability, and catalyst formulation in certain embodiments of the concept. The funding will enable the fabrication and operation of a prototype surface combustor to detemine performance data.

o To enhance aluminum recovery and product quality, an advanced concept for aluminum remelt can eliminate the problems of low efficiency, pollution caused by the combustion of paint associated with the aluminum, the loss of aluminum due to oxidation and the presence of hydrogen in the remelted aluminum. In this concept, the hot flame does not contact the aluminum; the fire tubes are immersed in the molten aluminum resulting in excellent heat transfer characteristics.

IGT recommends $0.5 million to initiate investigations of the advanced firetube aluminum melter. The initial work would center on the identification of materials to withstand the molten aluminum at elevated temperatures.

Hydrogen

A leading candidate for the fuel of the future is hydrogen derived by splitting water by using high temperature energy from nuclear fission, fusion or solar sources. To accomplish this, it is necessary to continue development of thermochemical or thermoelectrochemical cycles. Three hybrid cycles have been identified on a laboratory scale as having the potential to accomplish efficient and, ultimately, cost-effective water splitting. The three involve copper sulfate-copper oxide, zinc sulfate-zinc oxide, and cadmium chemistry.

IGT supports $3 million to continue the work on hydrogen research and specifically recommends $1 million for systems evaluations, including reaction kinetics, process/energy source interfaces, product purification and engineering optimization of the cycles.

THERMAL AND MECHANICAL ENERGY STORAGE

Thermal Energy Storage

Thermal energy storage benefits both energy efficiency and capital and operating costs. It can recover and store the energy exhausted in many processes for reuse, thus reducing primary fuel requirements, and it can improve the load factor of utilities by reducing added capacity requirements. IGT is developing a family of phase-change composite thermal storage media that allows direct-contact heat transfer. This concept has a wide range of applications from themal installations to utility load management. Significant cost benefits have been projected for these composite systems compared to conventional sensible heat storage systems. Proof-of-concept testing is now underway for industrial applications. Expanded R&D is needed in the identification of technical and economic goals for potential markets, measurement of physical and chemical properties of potential media materials, optimization of media thermal and physical behaviors within expected operating conditions, media selection/development to fit application temperatures and operating requirements, and study of materials compatibility between media, containment, working fluids, and auxiliary components.

IGT recommends $4 million for the intensified development of thermal energy storage using composite molten-salt phase-change materials.

Senator **Domenici**. I have one question for each of you and then I will yield to Senator Ford.

I have already asked Mr. Schora one. Let me just ask, go to Mr. Lee right now and ask you with reference to geopressurized methane in our program. There is a great deal of excitement about that, as I recall a few years ago, much discussion of this vast resource and the natural gas that might be associated with it, particularly in the gulf coast region.

At this date, could you give us some sense of how promising that resource is after we have spent this much time studying it and spent whatever moneys we have at this point?

Mr. **Lee**. That is a tremendous potential resource and the key part of it is much more R&D needs to be devoted to it to determine what is the amount of gas dissolved or trapped in free form with the brime. If there is free gas, as we have found in one or two cases, then this resource could add a huge amount of gas reserves to the Nation.

If it has just the amount of gas that dissolves in the brime but not enough to saturate it, then the amount of gas that is out there would be too small for it to be significant and economic. So what we have done in the past, I believe, is relied too much on the most optimistic projection and not enough work to ascertain the potential really by doing in-field R&D.

Senator **Domenici**. So it is still one of those where we ought to temper the excitement about the potential quantity because we do not know enough about it yet?

Mr. **Lee**. That is correct and we have a few design wells now operating that need at least, the money I was talking about, $5 million to keep them operating and keep collecting data that is complete and available. Once you miss a point or an opportunity to gather the data, you have lost an opportunity.

Senator **Domenici**. Mr. Philipp, on the fuel cell, you note in your testimony that a 4.8-megawatt demonstration in New York City has yet to operate successfully. We have been watching the development of that project now, I assume you have also, for 4 or 5 years I am just going to state a fact and if I am wrong, I am wrong—during that same period of time a very similar machine is already running in Tokyo, Japan. Is there something that we do not know about our utilities being an inhibitor of this, because of the way the utilities operate, as an inhibitor of new technology, maybe I should put it that way. Is there something about Tokyo's experience that does not translate over here? Maybe you could tell us about that.

Mr. **Philipp**. I think substantially from what I am aware, there are two reasons for it. One is that we purposely installed the first unit in a highly dense populated area, which has some very severe installation requirements. We did not count on these requirements and I think as a result of the restrictions that were placed on it, it did cause a substantial amount of delay and some problems.

Senator **Domenici**. Did the Japanese find a part of Tokyo that was not densely populated?

Mr. **Philipp**. The question really is that I am not aware of is what kind of restrictions did the Tokyo government place on the installation, and I am not aware of that. But I understand it is not as severe as the metropolitan area of New York.

Senator **Domenici**. The fire department in New York made them fill it full of water to see if it would hold it and then it got rusty.

Mr. **Philipp**. That is correct. It also became very cold out and did some freezing. The other reason is that Tokyo has a completely different design, the upgraded design to it, and for example, the stack was the new stack, the 10-by-10 stack, and this is also one of the causes for not being able to generate power, because there was some degradation that did occur in this old stack which was provided and it was not provided to the Tokyo one, because they had an opportunity to upgrade that. We are very conscious of it and we think that the problems are solved.

Senator **Domenici**. They must collectively laugh at us over there.

Mr. Lawrence, the pipeline and the distributors are very large in number and you as their representative are to be commended in my opinion, because you continue to focus on the year 2000 and beyond. You continue to focus, for instance, on coal gasification. You place emphasis on research needed in that area and that is actually compared to some other collective groups representing current business or businesses as usual that seem to not want to do that. A number of segments in my opinion have become more short-sighted rather than far-sighted because we have an immediate change of facts from 10 years ago.

We have more rather than less. Nobody is shutting down industries in Ohio or Illinois, but the facts have not changed very much and how could they? So let me ask you this, do you foresee a coal gasification being a significant source of natural gas for your industry in the year 2000 or shortly thereafter?

Mr. **Lawrence**. We see a potential, Senator, on the high side in the range of 10 percent of the total and while, when we compare the economics of coal gasification now with the conventional gas supplies in a tough, competitive market of $2.75 to $3 per million Btu's, it is a good bit higher, but when you compare the economics of coal gasification with the economics of how 75 percent of our coal is used today, and that is for generation of electricity, it compares very, very favorably.

If I could just add one other point. The Japanese are also very aggessive in their use of combined cycle electric power and steam generation where the turbines are run and the waste heat is used to generate steam. We could do that here if we would repeal the Fuel Use Act. I think one of the main reasons we want that accomplished is to lay to rest the fact that there will ever be a long-term gas supply shortage, which is something that does not have to be and that is why we have such tremendous research focused on areas that may be long term, like geopressure, like the gas hydrates in tight sands formation, in the coal seams and using current technology, single process, computer analysis combined with hydraulic geophysics brings that tremendous resource base into the commercial reality now.

Senator **Domenici**. I think I know how Senator Ford feels on fuel usability but we are not going to do much about that as a result of this hearing. Actually, I think you are absolutely right. We made a big mistake. I think the incremental pricing that was going to be the bonanza to residential home owners is a joke. If anything, it will cause higher prices for residences and I do not think we are going to be able to blame that on pipelines or natural gas producers. It is a result of our failure to understand the cyclical nature of business.

The price is going to be up because the industry is going to get off gas, because they are already. That is a disgrace for us. In any event I do not know if we will make any headway. We have a natural gas bill. Clearly those things need our support. If we did not have the rest of the problems, they would get the repeal on both sides of the aisle.

Senator FORD. I think we should get a limit on this piece of legislation—Fuel Use Act—rather than make it comprehensive. I think we go back to the situation we had in 1977 where it was a different approach, a different imagery and whatever. I think you and I were some of those that tried to warn some of our colleagues that the Fuel Use Act was too broad, but basically it was quid pro quo to get a bill out that we thought was necessary and we would yield.

Senator DOMENICI. You are right, but if you recall some of the Fuel Use Act limitations that they started with were more severe than we ended up with.

Senator FORD. The incremental pricing, we just sat there and looked at each other. It was not going anywhere.

Senator DOMENICI. I was running for reelection and that was a 7-month ordeal.

I have a question for Mr. Webb, which I will withhold and give it to you in writing.

Senator FORD. I have a couple of questions. I have read most of your statements and they all were very good. Mr. Lee, you have an interesting statement and I want to just talk with you about it, just for a few moments.

On the second page of your statement, the fourth paragraph, "A mature energy policy must preserve the environment. The acid rain issue is one of national and international concern." You also say in that same example that we have turned our back on coal and gone to the fascinating world of nuclear generating facilities, and all of those around me have gone down the drain, Marble Hill and Zimmer and all of those. Now, they are trying to turn Zimmer around and burn coal and it just does not work. It is too expensive.

It is hard to reemphasize something that has been beat over the head out here, like acid rain problems, and that is the issue of the day. If they would lower the present 1.2 pounds of emission per million Btu's generated to 1 pound, we would not have any coal left in Kentucky, which is the No. 1 producer of coal in this country to use. We would not have any left. We just could not make it.

I have got a very serious problem on my hands and as the distinguished chairman said a moment ago, the 10 million tons piece of legislation probably will fly out of the committee tomorrow and lo and behold, we have as much trouble with that as prayer in school getting it through the Senate, I think. So I will have to do my thing as best I can.

So let me ask you this question. Is there technology that in your own mind could be accelerated today that would give us the clean burning of coal and would not impose future harsh expenditures by the consumer ultimately because the technology would be outmoded in a short period of time, that you could recommend that we could to use today and ultimately would be an economical way to have clean burning coal?

Mr. **Lee**. Yes, indeed, Mr. Ford. The technology as I stated has fundamentally solved the acid rain potential by removing all of the pollutants during the gasification process. I would like to cite two examples. One, as you know, we use our agglomeration process evolved at IGT for this project in the city of Memphis. They are to convert coal, which could very well come from Kentucky, with high sulfur content, remove all of the sulfur and distribute a clean, industrial fuel for that area.

What we would like to recommend in our testimony is to extend that technology to higher pressures. By going to the high pressure, which is not now available in any of the facilities today and there is no funding for this, is take that to the high enough pressure range that we can produce, so-called synthesis gas. That gas can not only be used for fuel for burning, but more importantly it can be used for advanced power cycles, power generating cycles as well as provide a basis of synthesized methanol, gasoline substitutes, all of these fuels can come in the future. Fuel cells, as I mentioned earlier, are all feedstocks that can benefit by operating at higher pressures, a pressure range which is not now being investigated.

We feel very strongly that gasification is the fundamental way of solving it. I think you put it so well in your earlier remarks, that every incremental improvement in the tightening of environmental requirements that produces that much more of sludges and dry or wet sludges that have to be disposed of. The fundamental way to get rid of all this stuff is to do it in the front end, clean the fuel up. We appreciate your interest.

Senator **Ford**. Am I correct that it would take 3 Btu's of coal to get 1 Btu of electricity?

Mr. **Lee**. Typical current operation is just about, maybe it would do a little better. Probably 40 percent conversion, so it would be 2½ Btu's per Btu of power.

Senator **Ford**. For a country boy, that is close.

Mr. **Lee**. I do not want to shortchange you.

Senator **Ford**. I do not want to be shortchanged either, but I have been before, so it will not be something new.

How does this compare then to other things that we have out there?

Mr. **Lee**. If it produces the fuel and will be for making thermal energy, you will get for every Btu used, probably 1½ instead of 3 or 2½ in front. So you are talking about at least 70 percent efficiency in utilization. If you generate power through the combined cycle, you can get efficiency instead of 40 percent, which I mentioned was the best you can do with powerplants today that are on steam cycles, you can do 55 percent. If you use an advanced fuel cell, you can get up to 60 percent. So there is a tremendous improvement.

Senator **Ford**. The light just came on and it should not, Mr. Chairman, the light in my head.

Senator **Domenici**. What light?

Senator **Ford**. That one up there. It seems to me that here 3 or 4 years ago, there was an experiment in Wisconsin, I think, that would put electricity into a cylinder after it was generated, you can put that in and store electricity and then it would have about a 3- to 5-percent loss. It would circulate in some kind of a cylinder. It was fascinating to me, because rather than have your peak power part of your generating facility, you could let it run, that extra expense.

Is that envisioned somewhere? Does it mean anything to you?

Mr. **Lee**. Yes, there are many ways to store energy, especially power generated in the plants during offpeak hours. Some of these are storage batteries. It could be the kind you are thinking about. It could be chemical storage, converting these things to hydrogen, for example, as a storage of energy so you can burn it as fuel. There are thermal energy storage, the type that we are talking about. There are all sorts of ways you can store the energy and use it later before it would level off.

Senator **Ford**. Is this a super conducting magnet that I am talking about?

Mr. **Lee**. Well if that is what you are thinking of, sir, a super conducting magnet is a magnet that does not use the normal amount of power, because by lowering the temperature in which this magnet is immersed you can generate tremendous magnetic fuels without generating a lot of heat.

Senator **Ford**. At Los Alamos, I understood that some of the generation was going to be withdrawn and taken through the line as far as California and what I was looking at was the reduction in the cost of a generating facility and the reduction of having to have big power which would reduce the overall cost and reduce the pollution. It just seems like an idea.

But I want to tell you that fourth paragraph on your second page says a whole lot and your gasification cleanup on the front end and looking at all of the problems we have today that the midwest States, particularly Kentucky are doing, and are trying their best. They have already invested or have under construction $1 billion and have another $1 billion on the drawing board in reducing everything significantly and none in the Northeast, none in Canada and we are getting the brunt of all of this stuff and it bothers me a little bit.

Mr. **Lee**. If I may add one more thing, on this ash agglomeration gasification system that we are talking about, you can eliminate the particulite problem by it, agglomerate all of the ash to disposable discrete little beads that you can get rid of when they are disposed of properly and you can totally eliminate them. We think it is well worth the effort to invest in the ash chemistry studies as well as the process studies at higher pressure.

Senator **Ford**. Mr. Chairman, I have some questions for the panel that I will submit in writing and ask that they respond in a timely manner. I appreciate your cooperation.

Senator **Domenici**. No problem, Senator. Thank you very much.

Let me suggest with Mr. Lee with reference to the acid rain. I understand the problem that Senator Ford and the mid-American States are going to have, but I do not think it is totally fair to leave the impression that because we have a new process at some advanced level of R&D that that could solve this problem, because the problem is the existing sources that we would have to replace or retrofit or substitute for with practically new facilities. They themselves, that group, are causing the present pollution, if indeed that pollution is causing acid rain, which I guess there is a growing conclusion that one could at least accept that at least with as much certainty as we have accepted some of the premises in the Clean Air Act.

Senator FORD. The EPA says that we must have some to prevent the greenhouse effect.

Senator DOMENICI. I am not suggesting that we totally elminate everything in this process. I am merely saying that from the Senator's standpoint that argument that we have a new process that will totally clean up is not going to necessarily do much on the floor in terms of the debate, because the question is going to be when could you use that to replace what is presently producing the pollutant or how are you going to clean up the present pollution if you are not going to substitute?

So we are right back to where we were, it seems to me, other than the argument that we need more time. You are suggesting that if the argument is made we need more time that one premise that can be made is that there may be some new technologies like this to combine the cycle, that may need work. Is that correct? Do I understand you right?

Mr. LEE. I think you have made an excellent point, but we are not saying this is one new development. Coal gasification is a technology that we have been pushing for a long while. We need to look forward to getting the States set for the gradual replacement of our current source.

So it is not something that can be done overnight. There is no doubt about it. But I think it is important that this kind of development must be here today. Otherwise we will not have the technology ready when we need it.

Senator FORD. Mr. Lee, Senator Domenici said retrofit or replace and basically the fluidized combustion bed is almost retrofitting.

Mr. LEE. It is a retrofitting change of boiler configuration, less substantial retrofitting.

Senator FORD. I notice that this testimony earlier the department has taken a great deal of credit for being forced into the fluidized bed programs. They are taking credit for the $15 million this year and $15 million next year, which is going to Shawnee Plant at Paducah. And that 160 megawatt will use 600,000 tons per year of high sulfur coal. That is the way we plan to remove 90 percent or plus of the problem and we are getting into that sort of situation where you can use a low-cost coal, which offsets the expense of the better clean-burning coal.

We are well on our way to doing things that are necessary, I think, to expedite it and you find only one contribution by the Federal Government in that whole operation at Shawnee near Paducah.

In the State of Kentucky it is EPRI and people like that who are putting their money in trying to find an answer.

Senator DOMENICI. Thank you very much. We stand in recess. We appreciate your coming.

[Whereupon, at 1 p.m., the hearing was adjourned, subject to the call of the Chair.]

APPENDIX I

RESPONSES TO ADDITIONAL QUESTIONS

Department of Energy
Washington, D.C. 20585

June 25, 1984

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
Research and Development
Committee on Energy
and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On March 12, 1984, Assistant Secretary William Vaughan appeared before the Energy and Natural Resources Subcommittee on Energy Research and Development concerning the authorization for fossil energy.

Following that hearing, with your letter dated June 5, you submitted written questions for our response. Enclosed are the answers to those questions.

If you have any questions, please call Diana Diamond, Hank Edler, or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Paul Gilman
Mr. Al Astrin

Senate Energy & Natural
Resources, Energy R&D Sub.
3/12/84 Hearing
Senator Levin

Question 1: At some time in the future the United States will have to depend on liquid fuels produced by advanced technologies. When does DOE project the U.S. will dependent on coal liquefaction or some other type of advanced technology for 5% of our liquid fuels? For 10% of our liquid fuels?

Answer: Forecasts of energy supply and demand are subject to a great amount of uncertainty due to a variety of factors. Many forecasts made just a few years ago are now thought by many to represent extreme cases. Thus any long-term forecast can only be viewed as a possible outcome, that, along with other cases, should be considered for R&D planning purposes.

Two main determinants of when liquid synfuels are likely to account for a significant portion of domestic liquids consumption are the price of conventional liquids and liquid substitutes versus the price of liquids via advanced technology. The range of uncertainty is great for all of these. For example, a survey of a cross section of energy-knowledgeable people done in association with the development of projections for the fourth National Energy Policy Plan (NEPP) found the most likely estimated world oil price range between $36 and $57 in the year 2000 (1982 dollars per barrel), and between $55 and $84 in 2010. If one couples this with a $40 to $90/bbl. range that encompasses much of the uncertainty for various synthetic liquids products from different sources, then one could conclude that certain reasonable scenarios would have some synthetic liquids economically competitive during this century.

NEPP projections (Energy Projections to the Year 2010, October 1983) illustrate this point. For the higher world oil prices cited above, these projections show synthetic liquids from shale starting to penetrate the market near the end of the century, and reaching 12 percent of total domestic liquid consumption in 2010. Synthetic liquids from coal are projected to initially penetrate at a somewhat slower pace, reaching 6 percent of total domestic liquid consumption by 2010 for the assumed world oil price scenario.

Question 2: How far are we today from commercialization of the advanced technologies that would be required to produce 5% of our future liquid fuel needs? How far are we from the ability to produce 10% of our liquid fuel needs?

Answer: Commercialization of advanced technologies to produce liquid fuels ultimately will depend on market forces -- primarly the relative prices of competing liquid fuels. From a technological standpoint, there is no lack of technologies for producing liquid fuels. The current state of these technologies is briefly summarized below.

Two direct liquefaction processes (H-Coal, EDS) have been developed and tested at the large pilot plant scale (200-250 TDP). As a result of these successful operations, both of these processes can be considered technologically ready and available for licensing.

Two other processes (SRC-I, SRC-II) have been tested at a smaller pilot plant scale (20-50 TDP). These projects have previously been proposed for scale up to pioneer plant scale operation as part of the previous DOE demonstration program. This program was terminated in 1981, and the project sponsors were encouraged to apply to the Synthetic Fuels Corporation for assistance; however, they declined to do so.

Continuing process research and development, primarily under DOE sponsorship, has resulted in improved direct liquefaction process concepts such as staged liquefaction which can provide improved yields and product quality and reduced hydrogen consumption. These advanced processes are at the bench and/or proof- of-concept stage of development. Large scale development would be required before these improved processes could be considered technologically ready. Advanced coal liquefaction technologies may reach the commercial stage by the mid 1990's.

Indirect coal liquefaction technology is commercial in South Africa where three Sasol plants currently produce over 40% of that nation's transportation fuel requirements with varying forms of government support. The technology is available for licensing in the U.S. Research to improve the technology for U.S. application is supported largely by DOE to provide a catalyst and reactor system which will directly convert the synthesis gas from U.S. coals and modern gasifiers to quality gasoline, diesel, and alcohol fuels.

The first commercial oil shale plant using surface retorting technology is now undergoing commercial-scale startup tests. This technology has been undergoing intermittent development since the 1950's. Several technologies that began intensive development at pilot or semiworks scale in the mid-1970's are now commercial candidates in applications to the SFC. One advanced fluidized bed process is just starting tests in semi-works hardware or roughly at the stage of the earlier mid-1970's technologies. In fact, the Synthetic Fuels Corporation has issued letters of intent to three additional oil shale projects. The scale and maturity of other advanced oil shale concepts in the pipeline range from basic laboratory testing to completed pilot plant tests.

Other candidates include tar sands and underground coal gasification followed by indirect liquefaction.

Question 3: DOE intends to let industry finance the large expenditures required to achieve process development and commercialization of these advanced technologies. What is the magnitude of these projected expenditures?

Answer: It is difficult to project expenditures without referencing a specific technology. Process development will differ even in the same technology area depending, in large part, upon the equipment design, the intended market application, and corporate background of the developer. It can differ even more between technologies. For example, in Underground Coal Gasification we are estimating an expenditure of millions of dollars to reach commercialization whereas for an integrated two-stage direct liquefaction commercial capability, billions of dollars will be required. Only industry, based on market-place projections, should make decisions as to when and at what pace the technology should progress from proof-of-concept to commercialization. Only then can meaningful estimates of expenditures be developed.

Question 4: Does the private sector have the resources to finance these long-term projects?

Answer: We believe that the private sector has the resources to finance long term projects. Industry has demonstrated this ability to finance costly technologies when there are reasonable prospects for profits. The offshore oil production investment and deep gas exploration are excellent examples of industry's willingness to risk capital for potential profits. In addition, the Tennessee Eastern coal-to-methanol plant and Allis Chalmers coal gasification plant are examples where industry has borne the total cost of constructing a commercial scale plant.

Question 5: What are the incentives for private industry to make this investment?

Answer: Private industry's incentives to make such investment in synfuels technology is based on their expectation to achieve a reasonable rate of return on their investment. Each corporation's management decides what it considers to be a reasonable rate of return for the involved risks. The decision-making process is highly complex and considers a large number of variables and uncertainties. Typical factors for consideration are supply and demand projections for the product, cost of production versus cost of competitive products, financing costs (availability and cost of capital, interest rates, tax credits, etc.), and institutional constraints.

Question 6: Many of these technologies are 10 to 20 years, or more, away from commercialization. When will industry begin to invest the resources required to achieve commercialization of these advanced technologies?

Answer: Once federal research and development objectives have been accomplished, the pace at which new or alternative technologies are commercialized and marketed will be determined by entrepreneurs and consumers operating within the existing economic and regulatory framework. This pace is affected by a variety of interrelated factors, including existing and future perceived energy costs, local air and water quality standards, regional water availability, socio-economic impacts, and other factors such as the price and availability of energy imports, regulatory reform, tax and other investment incentives.

These factors tend to be complex and, in many cases, very unpredictable and thus federal R&D strives to put a capability in place which can be utilized by the private sector when it judges that conditions are favorable for commercialization.

Question 7: If we wait until the price of oil goes back up to $35 per barrel will we have enough lead time available to achieve a necessary level of commercial production?

Answer: The adequacy of a National capability to achieve a viable synthetic fuels industry in the future rests upon establishing a sound technology base. In the long run, synthetic fuels may make sense both economically and from an energy security perspective. Current projections do not point to energy shortages and large price increases in the relatively near future. However, in the long term, particularly as we move into the next century, our goal to foster an adequate supply of energy at reasonable costs, as well as our national economic and security interests, may lead to a situation where synthetic fuels are substituted increasingly for conventional fuels.

As part of our overall strategy of supporting a balanced and mixed energy resource system, we should have a base of some synthetic fuels experience. Then, if future market conditions warrant, U.S. industry can deploy the necessary synthetic fuels plants in an orderly, timely and rational manner. Thus, the U.S. does need synthetic fuels capability.

Effective deployment capability is not production capacity in place. Neither is it an arbitrary production goal of a certain quantity of synthetic fuel at some future date. Rather, it is an information base of verified data that is worth the cost involved. The information is not only technical and finanical but also includes knowledge that guides policy and regulation in such areas as environment, land and water management, licensing, and socio-economic development. These baselines are specific to a synfuel feedstock/technology combination. The better the information base, the better the future decisions will be by government and industry.

With Synthetic Fuels Corporation (SFC) support, a very limited number of diverse first-of-a-kind, commercial synthetic fuels plants operating in this country could provide the technical basis for an orderly, economic transition toward larger-scale synfuel production capacity if and when future market conditions dictated. Such pioneer facilities would also give decision-makers not only from the financial community, but from local, state, and federal regulatory agencies, the basis to establish appropriate guidelines and regulations. Early experience with commercial scale synthetic fuel facilities will be particularly important to industry, government, financial institutions, regulatory agencies, and others who may ultimately be called upon to decide whether, when, and how best to deploy future synfuel plants.

Currently, four major synthetic fuel projects have received federal support and are proceeding at various stages of design and/or construction:

- The Great Plains Coal Gasification Project - construction of which is now more than 97 percent complete - maximum $2.0. billion Loan Guarantee;
- Union Oil Shale Project - now in startup - maximum $400 million price guarantee with purchase commitment;

o Cool Water Gasification/Combined Cycle - now in startup - maximum $120 million price guarantee;

o Dow Syngas Coal Gasification Plant - now in design - maximum $620 million in price guarantees.

Two major coal conversion projects have been constructed and are currently being operated without any Federal financing:

o Tennessee Eastman Coal Gasification-to-Chemicals complex (now operating) near Kingsport, Tennessee;

o Allis-Chalmers Coal Gasification Commerical Module Demonstration Plant (now in startup) at East Alton, Illinois.

The Synthetic Fuels Corporation has also negotiated a letter of intent with the Great Plains sponsors pledging $790 million in price guarantees for the product. It is our hope and expectation that the Corporation will complete the price support agreement for this project. The project is in final start up activity and offers significant potential information benefits for the Nation's energy security.

In summary then, a strategy of conducting a judicious program of a limited number of first-of-a-kind commercial plants through the SFC and a technology base research program through the Department of Energy offers the greatest promise of developing a Synthetic Fuels capability in the time frame required to meet future needs.

Question 8: What will be the impact on the economy of another major (lasting longer than 6 months) disruption in the oil supply?

Answers: The Energy Information Administration (EIA), in its Annual Energy Outlook, 1983 (DOE/EIA 0383 (83)) analyzed the adverse affects to the U.S. economy on an oil price shock which could be caused by a disruption in the oil supply greater than 6 months. The report estimated that the impacts on the economy of another major (greater than 6 months) disruption in the oil supply are ultimately dependent on the monetary and fiscal policy responses which accompany the oil price shocks. It also indicates that significant redistribution of income away from energy consumers to energy producers occur when oil prices rise rapidly. "This, together with the reduced productivity of capital and the transfer of real income to foreigners, helps to cause significant economic dislocation -- the declines in consumption and investment which led to the 1974 and 1980 recessions. These effects on output and employment are basically unavoidable, although they can be minimized by pursuit of stable monetary and fiscal policies." The report maintains that if monetary authorities attempt to mitigate adverse effects on economic activity and employment by increasing the growth of the money supply to accommodate the rise in oil prices, the overall price level will rise permanently above what it otherwise would have been. "This is what occurred in the mid- and late-1970's following the two oil price shocks, when the CPI accelerated to double-digit rates. However, had policies been pursued to repress all the inflationary pressures of these energy price shocks, higher unemployment than was actually experienced may have been the result."

EIA concluded from their model analysis that, "The 2nd year (after the oil price shock) impacts (to GNP) are higher than those of the 1st year due to the lagged effect, especially on investment demand. In the 3rd year real GNP partially recovers, but even by the end of the 3rd year GNP has not fully recovered..." In summary EIA states that the first-year impacts on consumption expenditures, particularly expenditures on motor vehicles and parts and other durable goods, as a result of (a) sharp jolts to the inflation and interest rates, and (b) a sharp decline of the real income and wealth, cause most of the initial decline in the GNP. EIA goes on to say that a significant decline in investment is expected, peaking in the 2nd and 3rd year after the oil price shock, and that lost growth is accounted for by the lost hours and labor input during the 3 years. This loss could be more dramatic than that implied by differences in the unemployment rates because some workers become discouraged and tend to drop out of the labor force.

A summary comparison by EIA with other estimates of impacts based upon model simulations concludes that "there is clear agreement that economic welfare of the U.S. is vulnerable to political events adversely affecting world oil supply."

Further detail is included in the attached copy of the Economic Affects of an Oil Supply Disruption portion of the EIA Annual Energy Outlook.

Question 9: Other than SPR, which helps in the short term, how are we less vulnerable to a major oil supply disruption now, as compared to 1973?

Answer: As a result of conservation, improved energy efficiency and increased domestic production, the United States is less dependent on foreign sources today than in 1973. U.S. consumption of oil is down nearly 10 percent compared to 1973 levels, and net oil imports are down nearly 20 percent.

Residential and commercial buildings in the U.S. today consume 20 percent less energy per square foot than they did 10 years ago. Energy consumption per capita has declined by 13 percent since 1973. Energy input per unit of industrial output has declined by 23 percent. Similar improvements have been made in almost every sector of society.

Another reason we are less vulnerable is the current excess of world oil production capacity — the result of worldwide conservation measures and increased exploration for oil in non-OPEC countires. Oil exporting countries have been forced to restrict production to maintain prices at current levels, and these restrictions have resulted in additional excess oil production capacity. EIA estimates that world wide excess oil production capacity is presently 10-12 million barrels per day, of which 8 million barrels per day could be brought on-line very quickly in an emergency. Three of the eight million barrels per day originates from outside the Persian Gulf. There is enough excess capacity from the south end of the Persian Gulf to offset any loss of supply which might occur at the north end.

While the U.S. is less vulnerable to a major oil supply disruption now than in 1973, the Department is not complacent about the Nation's energy supply and is continuing to undertake those activities that move us towards our goal of adequate supply at reasonable cost.

Question 10: How does the market price reflect national security needs?

Answer: Energy security is but one element of national security. Yet it is an important one. Various aspects of energy security needs are reflected in market prices while other aspects are manifested by alternative supply arrangements which are established as insurance policies or hedges against unacceptable future market price disruptions. For example, both the Strategic Petroleum Reserve (SPR) and the private reserves held in this country and the stockpiles maintained by the other principal oil consuming nations are one form of "insurance policy".

A more fundamental energy market response has been the substantial increase in energy conservation and fuel switching in anticipation of future price rises. Over the past decade, industry and consumers have increasingly incorporated price expectations into their decisions to reduce oil use and are expected to continue to do so.

In summary then, to the extent expected future market prices (as contrasted to current transaction prices) for oil under conditions of a major disruption in oil markets are used as the basis for planning decisions, the diverse groups of oil consumers and producers are responding to the economic risks based upon their own assessments. By stimulating investments in hedges or insurance policies and of fuel switching and conservation, price expectations are the signal used by the marketplace to judge alternative measures to achieve energy security.

Question 11: Who has the responsibility to fund necessary research, development, and commercialization of technology necessary for our national security - industry or government?

Answer: The broad term national security includes both national defense and economic security. Whereas national defense investments involve the Federal Government as the purchaser and user of commercial defense technologies, this is not the case in other aspects of our overall economy, including the energy sector of the economy. The Federal Government does not have responsibility to ensure the adoption of new energy technologies by the private sector and generally is not the customer for such technologies. Its contribution to the development of future energy resources lies in the prompt and effective transfer of results from federally funded generic research and development activities to the private sector.

Federal R&D directed toward the early stages of the R&D cycle (basic and applied research) serves two critical purposes. First, it advances the frontiers of scientific and technical knowledge and provides the fundamental building blocks for technological innovation. Second, federal energy research and development programs support the development of new and alternative energy resources by providing scientific and engineering knowledge required for further development outside the federal sector.

Once federal research and development objectives have been accomplished, the pace at the which new or alternative technologies are commercialized and marketed will be determined by entrepreneurs and consumers operating within the existing economic and regulatory framework. This pace is affected by a variety of interrelated factors, including existing and future perceived energy costs, local air and water quality standards, regional water availability, socioeconomic impacts, and other factors such as the price and availability of energy imports, regulatory reform, tax and other investment incentives.

Question 12: How is spending to achieve energy security different than spending on weapons development?

Answer: As discussed in the answers to the previous two questions, the basic difference is in the role of the Federal Government. In the case of weapons development (national defense) the expectation is that the government will be the purchaser and user of the technologies. Therefore it can and should be in a position to make the decisions choosing the amounts and types of which weapons which should be developed. In contrast in energy technology development, since the government is not generally expected to be the purchaser and user of the technologies, it is not in a position to make the decisions about which technologies should be commercialized and at what rates. These should be made by the private sector.

Question 1: In your testimony you state that the Department's work on coal water slurries to be burned in utility plants will be phased out in FY85. Could you tell us the results of that Program? How successful has this use of coal been? What are the prospects that coal water mixtures can be used in other applications?

Answer: The coal-water slurries program for utility and large industrial boiler applications has been very successful. As you know, DOE's role in this activity is to develop and make available to the private sector a coal water slurry combustion and component characterization data base that is suitable for corporate decisions on the commercial use of this technology.

The private sector selected to develop specific coal water slurry fuels (which are considered proprietary) and, in most instances, have pursued this activity with vigor. In many cases, they have established marketing and engineering capabilities in pursuit of commercial implementation. No less than seven major companies are represented in this category. Among them are Oxidential Petroleum, Combustion Engineering, Ashland Oil, Babcock and Wilcox, Altantic Research, Allis Chalmers, and Foster Wheeler.

Based on these developments, the R&D questions related to the use of coal water slurries in utility and industrial boilers have largely been answered. The private sector will likely proceed with commercial projects as market conditions permit. As a result, the Department has concluded that additional Federally-funded R&D is no longer necessary. However, it is our belief, based on our technology assessment, that coal liquid mixture fuels have a much broader application base than just utility and large industrial boilers. We have identified sizable potential markets in the commercial, institutional and residential arenas for boiler/furnace applications, and a significant market potential in heat engine (diesels and turbines) applications. We are proposing to conduct R&D in these areas.

Question 2: Mr. Secretary, coming from a State which is turning more and more to the use of techniques for enhanced oil and gas recovery I guess I have an appreciation for the importance of this research and the risks involved in the technology. This is the second year in a row the Department has thought to increase the funding for enhanced oil recovery. Last year in both the Appropriations process and the Authorizing process less was allocated for this research than was requested? Do you have any suggestions for how we can more successfully make the point as to how important this research is? I certainly would support the Administration's request.

Answer: We share you concern for adequate funding of DOE Enhanced Oil Recovery and Unconventional Gas Recovery programs. As clearly indicated in the recent draft report of the National Petroleum Council's Committee on Enhanced Oil Recovery, extensive research must be undertaken by both the private and government sectors to remove the technical impediments to commercialization of enhanced recovery processes.

Question 3: Mr. Secretary, as you know there has been a great deal of interest in the potential resource of natural gas which may be found very deep in the earth. Could you give us some idea of the results of the research that has been done on these so called abiogenic gas resources?

Answer: Based on the DOE sponsored workshop, held in Morgantown, W.Va., in May of 1982, it is DOE's opinion that the subject of natural gas resources of deep origin is best addressed through the term "deep source gas," which encompasses three separate concepts. Each of these concepts are unique and require separate research methodologies. The three concepts are as follows:

1. Abiogenesis — Referring to non-biologic origin gas primordially emplaced in the earth's mantle.

   Preliminary assessment of the abiogenic theory is ongoing at Cornell University under contract to the Gas Research Institute. This assessment will examine all phenomena attributed to methane outgassing that has occurred throughout the world.

2. Subducted Organic Origin Gas — A plate tectonic methodology for deeply emplacing hydrocarbon-generating ocean sediments in the earth's crust and mantle.

3. Deep Sedimentary Basin Concept — A more conventional idea relating to gas generated from known, deeply down-warped sedimentary rocks, such as those of the Deep Anadarko Basin of Oklahoma.

Both concepts 2 and 3 are the subject of study in DOE's Deep Source Gas Project. The main focus has been activities in the Subducted Organic Origin Gas hypothesis as a means of gas emplacement. This METC developed idea, along with the more conventional "Deep Sedimentary Basin" concept (involving gas generated at depths below 30,000 feet in deep basins, like the Anadarko of Oklahoma) are being actively investigated by both in-house and contract research (currently USGS, Texas A&M, and the University of Arizona). The aim of this effort is to establish the existence of natural gas arising from these depths, tie these occurrences to conceptual models, define the limits of target areas, quantify the resource, and determine its significance to the nation's reserves.

To date the results of this effort include the following:

- Extensive geologic reconnaisance of western North America establishing its potential for deep-subducted hydrocarbons.
- Geophysical evidence of thick-subducted sediments at great depth in western Washington.
- Completion of preliminary studies in the Brooks Range of northern Alaska which indicate potential for deeply emplaced source rocks.
- Description of the plate tectonic and geochemical history needed to evaluate deep source gas potential in northern California.

APPENDIX II

ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD

For the Record

AGA American Gas Association

1515 Wilson Boulevard, Arlington, Va. 22209
Telephone (703) 841-8400

George H. Lawrence
President

March 13, 1984

Honorable Pete V. Domenici
Chairman
Subcommittee on Energy Research
and Development
Energy and Natural Resources Committee
United States Senate
Washington, DC 20510

Dear Mr. Chairman:

During yesterday's hearing on the Department of Energy FY1985 Research and Development budget, Senator Wendell Ford and you asked a number of questions on the subject of acid rain. One of your questions dealt with how an existing facility can comply with the Clean Air Act using currently available technologies. Due to time constraints on the part of the subcommittee, a complete discussion of this important subject was not possible. I thought it might be useful to you, Senator Ford and other members of the subcommittee if I provided you with a synopsis of our industry's concept of the select use of gas to meet environmental problems. Attached is a portion of the testimony I recently presented to the Senate Environment and Public Works Committee. In that statement, we outlined an SO_x or particulate control strategy, the select use of gas with coal, which does not require significant capital expenditures or sharp increases in electric bills. As part of that testimony, we listed sixteen facilities already using select use to comply with the Clean Air Act. I request that this statement on the select use of gas be included at the appropriate point in the record of yesterday's hearing.

If you have any questions, or if we can provide any additional information, please don't hesitate to contact me, Mike Baly (703/841-8612) or Diane Brown (703/841-8591) of my staff.

Sincerely,

George H. Lawrence

cc: Sen. Wendell Ford

THE
SELECT USE OF NATURAL GAS
FOR
IMMEDIATE SULFUR DIOXIDE EMISSIONS REDUCTIONS

Select Use of natural gas is an easily implemented and economical technique of reducing sulfur dioxide air pollution. It involves mixing natural gas -- which emits virtually no sulfur oxides when burned -- with more polluting fuels, such as coal or high sulfur oil. Clean burning natural gas can offset or reduce the amount of air pollution that would have been emitted if just coal or high sulfur oil were burned.

Its carbon dioxide, carbon monoxide, nitrogen oxide, and non-methane hydrocarbon emissions are all lower than oil or coal. For example, a large gas boiler (either industrial or power plant) on average emits only .0006 pounds of SO_2 per MMBtu, while a boiler on an average grade of residual fuel oil (1.5% sulfur) emits 1.6 lbs SO_2/MMBtu. A similar boiler operating on 2% sulfur coal emits 3.4 lbs/SO_2/MMBtu. In a well-known case, the Narragansett Electric Company in Rhode Island used the clean burning attributes of natural gas to offset emissions from a switch to a higher sulfur oil. In the past, the utility operated two boilers on expensive low sulfur oil. In order to reduce fuel costs, it switched one boiler to high sulfur oil and the other to natural gas. By converting a single boiler to gas, the company was able to offset the increased SO_2 from the high sulfur oil and actually reduced both its fuel cost by $2 million a year and its SO_2 emissions by 1,388 tons/year. This same strategy can be used with Eastern high sulfur or Western low sulfur coal. The following charts show the amount of natural gas (in percentages) that could be used with coal or oil, with varying sulfur contents. The percentages vary, of course, with the stringency of local limits on SO_2 emissions (shown on the left axis). These data show the significant environmental benefits of using natural gas.

PERCENTAGE OF FUEL MIX REQUIRED TO BE GAS FOR VARIOUS GRADES OF COAL AND SO_2 EMISSION LEVELS

SO_2 SIP (lb./MMBtu)	Sulfur Content of Eastern Coal[2]				Sulfur Content of Western Coal[3]			
	.8%	1%	2%	3%	.8%	1%	2%	3%
0.6	53%	62%	81%	87%	61%	68%	84%	89%
0.8	37	49	75	83	47	58	79	86
1.0	22	37	68	79	34	47	74	82
1.2	6	24	62	75	21	37	68	79
1.4	–	11	56	71	8	26	63	75
1.6	–	–	50	66	–	16	58	72
1.8	–	–	43	62	–	5	53	68
2.0	–	–	37	58	–	–	47	65
2.2	–	–	31	54	–	–	42	61
2.4	–	–	24	49	–	–	37	58
2.6	–	–	18	45	–	–	32	54
2.8	–	–	12	41	–	–	26	51
3.0	–	–	5	37	–	–	21	47

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[1] *Select Gas Use for Environmental Purposes*, American Gas Association 20 (January, 1983).

[2] 12,000 Btu/lb.

[3] 10,000 Btu/lb.

PERCENTAGE OF FUEL MIX REQUIRED TO BE GAS FOR[1] VARIOUS GRADES OF RESIDUAL OIL AND SO_2 EMISSION LEVELS

SO_2 SIP (lb./MMBtu	Sulfur Content of Oil				
	.25%	.5%	1%	2%	3%
0.2	23%	62%	81%	90%	94%
0.4	–	23	62	81	87
0.6	–	–	43	71	81
0.8	–	–	24	62	75
1.0	–	–	5	52	68
1.2	–	–	–	43	62
1.4	–	–	–	33	56
1.6	–	–	–	24	49
1.8	–	–	–	14	43
2.0	–	–	–	5	37
2.2	–	–	–	–	30
2.4	–	–	–	–	24
2.6	–	–	–	–	17
2.8	–	–	–	–	11
3.0	–	–	–	–	5

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[1] *Select Gas Use For Environmental Purposes*. American Gas Association 21 (January, 1983).

Choosing the Most Efficient Sulfur Oxide Control Strategy: The Benefits of Natural Gas

With select use of gas, the cost of sulfur oxide reductions can vary from \$50/ton of SO_2 removed to over \$1000/ton. This range of costs is not unusual considering the many variables, such as state set emission limits, and fuel and equipment costs, which can change dramatically from site to site. A study by ICF, Inc. a consulting firm, postulated a range of control costs for fuel switching (high to low sulfur coal or oil) and scrubbing from \$250 - \$2000/ton. When one considers that many select use options fall in the \$200 - \$400/ton range, the reader can immediately see that gas and coal or gas and high sulfur oil mixtures are economical alternatives to scrubbing or fuel switching.

For completeness, the ICF \$250 - \$2000 cost range for non-select use control options is:

Representative Annualized Costs of SO_2 Reduction Alternatives*

Control Strategy	\$/ton SO2 Removal (mid-1982 dollars)
Shift from High- to Low-Sulfur Coal**	\$ 250 - \$ 300
Shift from High- to Medium-Sulfur Coal**	350 - 400
Shift from Medium- to Low-Sulfur Coal**	400 - 450
Shift from High- to Low-Sulfur Residual Oil	450 - 600
Shift from Unscrubbed to Scrubbed High Sulfur Coal***	400 - 500
Shift from Unscrubbed to Scrubbed Midium-Sulfur Coal***	600 - 1,100
Shift from Unscrubbed to Scrubbed Low-Sulfur Coal***	1,200 - 2,000

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*Cost will vary considerably, depending upon region and plant size. Costs per ton presented in this table are intended to be representative of average control costs only.

**Costs include upgrading particulate removal equipment.

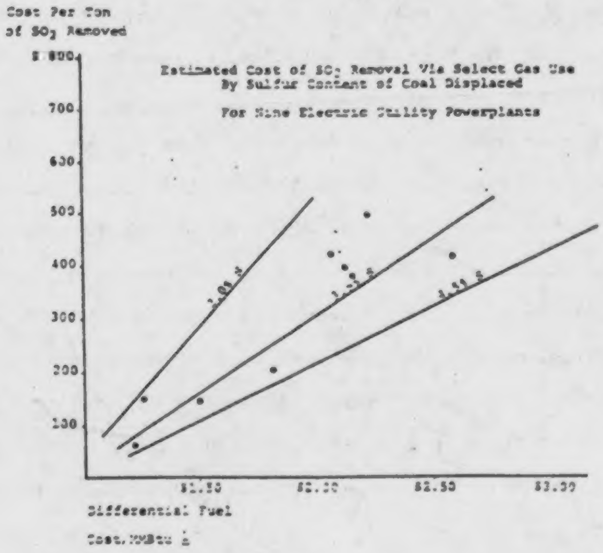
***Based on retrofit scrubbing costs for a 500-megawatt powerplant.

Source: ICF, Incorporated

We think, however, that ICF may have understated the costs of a massive switch to low sulfur coal. For example, the model tends to understate the costs of increased rail transportation. Also, the other effects of fuel switching need to be considered. These include unemployment in Eastern coal mines, plant derating, and increased solid waste disposal.

In many situations, but not in all or even necessarily most, select use can be the most economical control option. In addition to the quantifiable benefits of Select Use, we should also mention its intangible benefits. For example, Select Use is a flexible control strategy that can be combined easily with other technologies. Select Use and low cost coal washing could reduce SO_2 by 50% or more while continuing to use 70% or more of Eastern high sulfur coal. This is in sharp contrast to low sulfur coal fuel switching which could cut Eastern coal consumption to 25%, in the worst case.

Although the immediately preceding pages have been devoted to Select Use with coal, natural gas mixtures are also an excellent way to lower high sulfur oil emissions. There are hundreds of power plants and industrial facilities that could use gas/oil mixtures either in adjacent boilers, or in the same boiler. Professor Alex Green of the Interdisciplinary Center for Aeronomy and Atmospheric Sciences at the University of Florida estimated in 1980 that consumers could save $12.5 billion per year in electricity costs by switching 100% oil-fired powerplants to gas mixtures. (While the Green work is becoming dated, the bottom line is still clear: the potential savings are large.) The following chart graphically displays the site specific benefits of select use at nine powerplants.



a Cost of Gas - Cost of Coal

Note: Assumes O&M of coal-fired utility boiler exceeds gas boiler O&M by $1.00/MMBtu based on information contained in: Thermal-Electric Plant Construction Cost and Annual Production Expenses, DOE EIA.

• - Represents actual plant operating data (cost of gas, cost of coal, sulfur content of coal) for December, 1982. See: Cost and Quality of Fuels for Electric Utility Plants, DOE/EIA.

Select Use Is a Feasible and Well-Proven Technology

A special advantage of Select Use is that it can be implemented quickly, with very low capital costs. One possible research project which would reduce SO_2 emissions quickly involves the implementation of the Select Use concept on an interim basis. By employing a select use sulfur oxide control strategy on an interim basis, any changes in the acidity of rain and lakes could be monitored and any cause and effect relationships between emissions and this acidity could be better assessed. This strategy avoids the long lead times and large investments for major pollution control equipment, as well as the economic dislocations of high to low sulfur coal switching. It also preserves future SO_2 control options so that -- _if_ research pinpoints acid rain sources -- flexibility is retained as to the optimum permanent course to pursue.

A.G.A. recently compiled a list of facilities that use some mixture of natural gas and another fuel. This tabulation shows that Select Use is a control strategy that we can use here and now.

Examples of Select Gas Use Applications

State	Company	Gas Used in Conjunction With
NJ	Atlantic City Electric [1/]	Coal
MA	Boston Edison	Oil
RI	Narragansett Electric	Oil
PA	Andre's Greenhouse	Oil
AL	3M	Oil
CT	Uniroyal	Oil
VT	Burlington Electric	Oil
PA	U. S. Steel	Coal
PA	Scott Paper	Oil
PA	Arbogast & Bastian	Oil
PA	J. H. Thompson	Oil
PA	U. S. Steel	[2/]
PA	Bellefield Boilers	Coal
MO	Springfield Utilities	Coal
NJ	Public Service Electric and Gas	Coal

[1/] Company operated on a 50:50 gas/coal mix from 1980 through 1982 for SO_2 control while scrubbers were being installed; no longer using gas.

[2/] Natural gas used to offset SO_2 emissions from various coke ovens, soaking pits, boilers, furnaces and other steel industry operations.

Natural Gas Supplies Are Abundant: The Gas Industry Is Well Able To Satisfy The Select Use Market.

If plant operators can choose Select Use, as one of many options, as much as 1 Tcf/year of natural gas might ultimately be used for environmental compliance. Nationally, the natural gas industry is quite capable of supplying this market. 1 Tcf/year is only approximately 5% of current or projected yearly U.S. production. At the present time, we estimate that the U.S. has as much as 3-4 Tcf excess deliverability: that is, gas shut-in or not taken. A 1 Tcf investment could translate into a 2 million ton/yr. SO_2 reduction. By combining Select Use with coal washing, that same 1 Tcf could reduce SO2 by nearly 4 million tons/year. This strategy also reduces NO_2 and particulate emissions, as well as solid wastes.

Furthermore, future gas supplies are ample. A.G.A.'s Gas Supply Committee - which is made up of a broad spectrum of gas industry experts -- recently revised our independent supply forecast for the end of this century. The Committee considered three different policies:

- North American Self-Sufficiency, in which the nation relies entirely on lower 48 state resources, Alaskan gas, and Canadian and Mexican imports;
- High Alternative Fuel Prices, in which world crude oil prices rise somewhat rapidly, thus pushing-up gas prices; and
- Low Alternative Fuel Prices, in which world crude oil prices rise less rapdily, thus restraining gas prices.

In each and every case, gas supplies were adequate in the year 2000. The average supply estimate for the three scenarios, which appear below, is 22.4 Tcf in 2000 -- an increase of 20% over actual gas supplies in 1982.

TABLE I-1
GAS SUPPLY-2000
(in Tcf)

Scenarios	Self-Sufficiency	High-Price Alternative Fuels	Low-Price Alternative Fuels
Conventional Lower-48	15-16	14-15	12-13
Incremental Tight Formations	2-3	1-3	0.3-1.5
Total Lower-48	17-19	15-18	12.3-14.5
Alaska	1.4	0.9	0.8
Canada	2.4	2.4	1.5
Mexico	1.5	1.0	1.5
LNG	0.2	1.0	0.2
Coal Gas	1.5	1.0	0.3
SNG	0.1	0.1	0.2
Nonconventional	0.6	0.4	0.2
Totals	24.7-26.7	21.8-24.8	17.0-19.2

It is important to note that our revision considered the following "economic realities": (a) a slowdown in the rate of economic growth, factoring in uncertain interest rates; (b) declining U. S. demand for all forms of energy, due to conservation and increasingly efficient processes; and (c) a new slant towards conventional oil and gas supplies and away from synthetic fuels.

Although these three factors may all operate to check gas supplies, the overall forecast still reveals a healthy range of gas supplies from a low of 17 Tcf to a high of 26.7 Tcf.

Summary

The benefits of multiple control strategies for SO_x reductions are many. Select Use, in particular:

- Maximizes the use of Eastern coal and minimizes the economic and social dislocations among mining communities;
- Avoids plant derating, increased solid waste, increased particulates, and railroad transportation problems associated with straight coal strategies;
- Offers prompt emission reductions since new equipment or plant modifications are minimal in most cases.
- Can buy the nation valuable time since Select Use can be used temporarily to reduce emissions quickly while research is ongoing; and
- Avoids the high capital costs of a mandatory scrubber program.

With myriad benefits, Select Use is a vital alternative for the nation to consider. Now is the time to take advantage of the environmental benefits of our cleanest burning fossil fuel, a long term adequate supply of which appears very attainable. We can do that by: (1) repealing incremental pricing and the Fuel Use Act ban on gas use by powerplants and industry; (2) ensuring that if SO_2 control legislation is enacted, it mandates performance standards rather than specific fuels or control strategies; and (3) urging the Environmental Protection Agency to accept Select Use as a control technology under existing provisions of the Clean Air Act.

March 12, 1984

Select Gas Use

Select gas use, or "select use," is a term that refers to a relatively new concept in fuel combustion—the burning of natural gas with less environmentally attractive fuels (e.g., coal or oil) in the same or separate combustion units for environmental purposes.

The simplest select use method—burning gas in one combustion unit to offset the emissions from some other fuel being burned in a separate unit—is not constrained by any technology barrier. A second select use mode involves the co-firing of gas and a lower-quality fuel in the same combustion unit. Large utility boilers have operated on a gas/coal mixture, but the experience to date has been very limited.[21]

Select use offers a variety of benefits, both to the fuel consumer and to the nation as a whole. From a national perspective, select use can: reduce our dependence on imported oil, maintain or improve air quality; increase our reliance on domestic coal (and gas); and, enhance the employment outlook for eastern and midwestern coal miners. For the energy consumer, select use can: reduce overall fuel costs; reduce susceptibility to fuel supply disruptions, such as a coal or rail strike or an oil embargo; increase flexibility in siting new facilities; and preclude the need to purchase expensive pollution control equipment.

Select use is a pollution control strategy which offers significant advantages by reducing capital expenditures for control equipment and by reducing operating costs.

In a study prepared by the American Gas Association (A.G.A.), the cost of converting 12 New England powerplants to select gas use was compared to the cost of converting all 12 plants to coal-fired operation with SO_2 scrubbers, and to the cost of a continued dependence on oil for all power generation. On an annualized life-cycle cost basis, the select use option was found to be 15 percent less costly than continued oil operation, and select use also would reduce oil imports by roughly 100,000 barrels per year (15 percent of New England's total oil consumption).

By comparison, converting to coal with scrubbers would cost New England electric consumers 10 percent more than the select use option—the select use option would cut the capital expenditures and annual maintenance expenditures by approximately one-half relative to the scrubber case, while meeting the same emission standards.

Select use can provide a more cost-effective means of powerplant SO_2 control than flue gas desulfurization ("scrubbing").

ICF Inc., according to a study prepared by the Congressional Research Service of the Library of Congress, has estimated the cost per ton of reducing SO_2 emissions from powerplants via a number of alternative control strategies.[22] They estimate that shifting from high- to low-sulfur coal would entail a cost of $250 to $300 per ton of SO_2 removed, while the addition of scrubbers to these units would cost far more—from $400 to $2,000 per ton of SO_2 removed. Analyses by A.G.A. indicate that the SO_2 removal cost by the select use option is in the $200 to $400 per ton range in many cases, although the cost may be as low as $50 per ton for some facilities and over $1,000 per ton for others.

Recent liberalization of EPA's "bubble policy" enhances the potential for select gas use.

With EPA and state approval, it is now possible to average the emissions (*i.e.*, "bubble") from various individual emission points within a source so that the emissions from the entire source are less than what its emissions would be without the bubble. This policy not only ensures that air quality standards are met, but it also provides companies with the flexibility to find their own optimal pollution control strategies.

As an example, the Narragansett Electric Company in Rhode Island operates two generating stations less than one mile apart. In the past, each unit burned 1 percent sulfur oil. However, under a recently approved bubble, one unit may now burn 2.2 percent sulfur oil while the other burns natural gas. As a result, the utility expects to save $2 million to $4 million per year in fuel costs, SO_2 emissions will be reduced by 1,388 tons per year, and oil imports will drop by 600,000 barrels per year.[23]

Initially, it is likely that the select use option will be pursued primarily by large industrial facilities and electric utilities; however, the fuel consumption patterns of these potential users are constrained by both the Fuel Use Act (FUA) and the Clean Air Act (CAA).

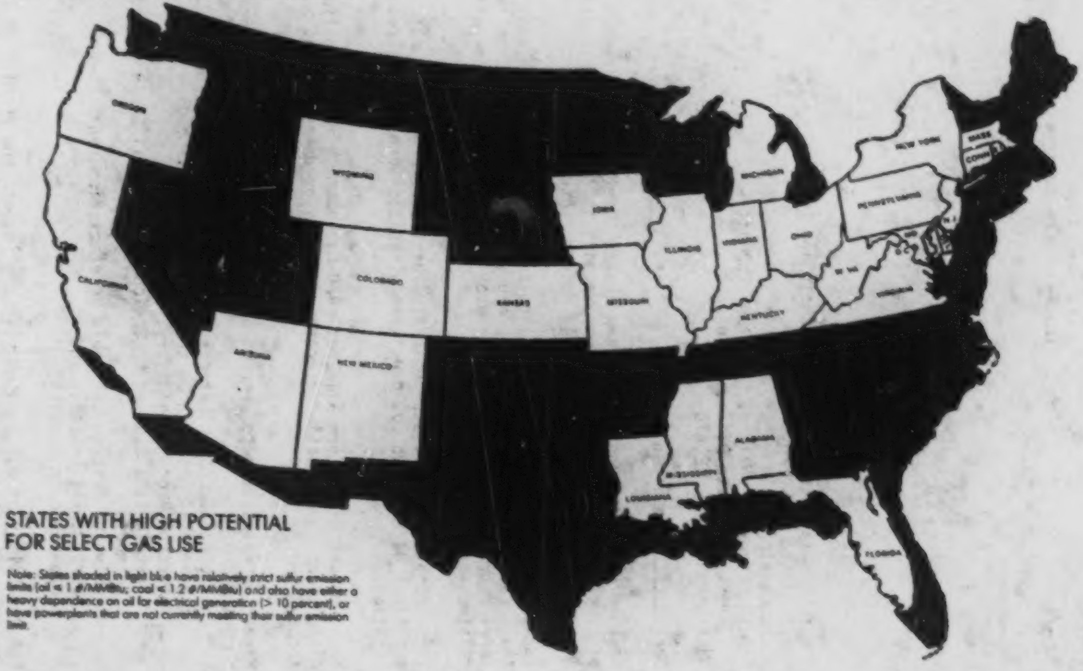
Two pieces of legislation enacted in the 1970s—the Clean Air Act of 1970 (as amended in 1977) and the Powerplant and Industrial Fuel Use Act of 1978—significantly affect the fuel consumption patterns of major industrial facilities and electric powerplants currently in operation, and will affect those to be constructed in the future. The Fuel Use Act was passed in an attempt to shift the energy dependence of large facilities from oil and gas to coal in the belief that oil and gas supplies were running out. The Clean Air Act was intended to preserve and improve this nation's air quality.

The impact of these two acts on select use may be minor at existing facilities. However, the select use option will be extremely difficult to pursue for new large facilities (both boiler and non-boiler), and moderately difficult to pursue for new, small facilities, in light of the combined impact of the FUA and CAA.

The success of select use will depend on a variety of site-specific variables.

The extent to which select use is successful will depend on a number of variables, some of which are site-specific, including: emission limits (both the allowed emission level *and* the manner in which regulations are applied), fuel cost differentials by quality, the bubble policy (and possible expansions or restrictions to that policy), oil dependence, and technological innovation.

Based on an examination of these variables, the map on this page indicates those areas of the country expected to have a relatively high potential for select use — although select use application will certainly not be limited only to these areas.


OREGON
CALIFORNIA
WYOMING
COLORADO
ARIZONA
NEW MEXICO
KANSAS
IOWA
MISSOURI
ILLINOIS
INDIANA
MICHIGAN
OHIO
KENTUCKY
W. VA.
VIRGINIA
PENNSYLVANIA
NEW YORK
MASS
CONN
N.J.
MD
LOUISIANA
MISSISSIPPI
ALABAMA
FLORIDA

STATES WITH HIGH POTENTIAL FOR SELECT GAS USE

Note: States shaded in light blue have relatively strict sulfur emission limits (oil ≤ 1 #/MMBtu; coal ≤ 1.2 #/MMBtu) and also have either a heavy dependence on oil for electrical generation (> 10 percent), or have powerplants that are not currently meeting their sulfur emission limit.

STATE OF INDIANA
EXECUTIVE DEPARTMENT
INDIANAPOLIS 46204

JOHN M. MUTZ
LIEUTENANT GOVERNOR

March 16, 1984

The Honorable Pete V. Domenici, Chairman
Subcommittee on Energy Research
and Development
Senate Energy and Natural Resources Committee
2317 Dirksen Senate Office Building
Washington, D.C. 20510

Dear Mr. Chairman:

As Lieutenant Governor of Indiana and as Director of Indiana's Department of Commerce, I appreciate the opportunity to submit this letter of testimony supporting Eastern Oil Shale Research and Development.

Indiana has an estimated 40 billion barrels of oil locked away in its oil shale resources. As a synthetic crude oil, it could help balance our national energy trade deficit while providing jobs through new oil shale related industries.

This resource is very strategically located near existing oil refineries and final markets and could utilize a capable work-force already on location.

Your support of Eastern Oil Shale R&D could ameliorate potential supply disruptions in our nation's economy, should overseas sources be jeopardized.

Several areas appear to warrant allocation of funds, including:

Eastern Oil Shale Characterization;
Fundamental Research on the Shale;
Retorting Process Chemistry;
Cost-Effective Studies on Various Eastern Oil Shale Retorting Methods;
Studies on Eastern Oil Shale Beneficiation (enrichment);
Environmental Impacts; and
Socio-Economic Studies.

The volatility of our foreign oil supplies and the promise of this critical resource appears to warrant your thoughtful consideration.

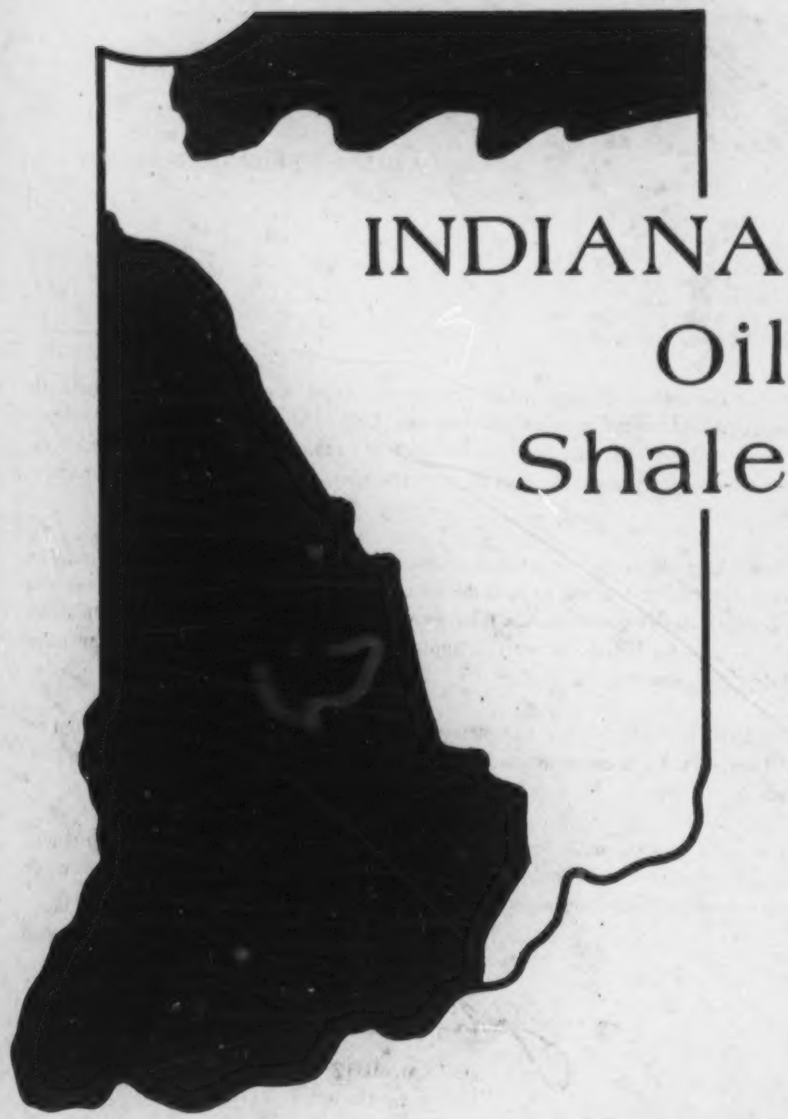
Additionally, it is my pleasure to offer the enclosed book "Indiana Oil Shale" for your additional information. If you have any questions, please feel free to call me at 317/232-4545.

Sincerely,

John M. Mutz
JOHN M. MUTZ
Lieutenant Governor

JMM:rm

Enclosure



INDIANA Oil Shale

Division of Energy Policy
Energy Resource Development Section
Indiana Department of Commerce
Lieutenant Governor John M. Mutz, Director

A MESSAGE FROM THE DIRECTOR

As Director of the Indiana Department of Commerce it is my responsibility to oversee both economic development and energy resource development. One of the primary goals of our Division of Energy Policy is to identify and help develop Indiana's indigenous native energy resources. Under the proper circumstances, they can provide domestic energy supplies and create jobs in new energy industries.

We are enthusiastic about the potential of Indiana's oil shale. Indiana possesses billions of barrels of oil shale reserves that could help us decrease our balance of energy trade deficit and a commercial oil shale industry could provide thousands of jobs for Hoosiers. Since oil shale development is a new concept for Indiana, it must be approached carefully in order to insure environmentally sound development.

Indiana Oil Shale is the state's first complete shale information booklet. It was prepared by the Division of Energy Policy in consultation with various state and federal agencies, private concerns and individuals.

I hope you will find *Indiana Oil Shale* informative and enlightening. Oil shale development in Indiana, if accomplished in an environmentally and economically sound manner, can mean the development of a new and abundant resource that will benefit all Hoosiers.

Sincerely

John M. Mutz

JOHN M. MUTZ
Lieutenant Governor

INTRODUCTION

Oil shale hints at a future of energy independence and secure jobs for Hoosiers. But this emerging industry faces several challenges, including environmental guidelines and uncertain economic projections. Oil shale development is continuing in Indiana, motivated by the potential for a vast new energy reservoir which could decrease American demand for conventional energy sources.

Both the state and federal governments will continue to play large roles in oil shale development. Indiana is concerned that energy needs are met in a way that also satisfies environmental quality concerns. But for now, most experts agree that economics are the major factors delaying oil shale development.

It is unlikely that the growth of the oil shale industry will be as explosive as the oil booms of the past. Today the gains and gambles of the new industry are being weighed more carefully. Development is proceeding with caution. Research into better and more efficient production processes is presently being conducted, and studies of environmental effects are under way. In general, there is guarded optimism for the industry. Perhaps, after being an "almost" industry for so long, oil shale will soon turn the corner into commercialization as a profitable and environmentally well managed industry.

A BRIEF HISTORY OF OIL SHALE DEVELOPMENT

During the initial stages of oil shale development in this country both federal agencies and major oil companies focused attention on western shale.

Probably the biggest reason for early development of western oil shales, besides oil yield, is the fact that the deposits were part of the public domain. Until 1920, oil shale deposits could be staked and claimed like other minerals on federal land and federal programs encouraged oil shale development on federally owned land.

Western shale yields more syncrude (liquid oil product) per ton than Indiana's shale by standard retorting methods. However, the total energy obtainable from eastern oil shale is about the same, if one includes the Btu content of gaseous product and residual carbon.[1]

Technology has become more efficient and it is now feasible to develop eastern shale and obtain similar Btu values found in western shale. The western shale deposits are located where the exceptionally large and expensive processing plants could easily develop shale oil during a time of inexpensive money. Today, several economical modular plants, rather than one large plant, would probably be used. This is attractive environmentally because there will be less shock to the industry's surroundings, allowing less expensive reclamation.

INDIANA'S OIL SHALE RESOURCES

Indiana's shale is a brownish-black rock consisting of layers of sediment laid down eons ago during the Mississippian and Devonian Periods in epicontinental seas. In this rock is a solid organic material called kerogen, a complex mixture composed mainly of carbon, hydrogen, oxygen, sulfur, and nitrogen. Rich deposits of organic matter found in shale can contain up to 50 percent kerogen.[2]

The kerogen is processed by heating the shale rock to release liquids and gases. Heating breaks the chemical bonds holding the heavy kerogen molecules together and "cracks" the individual large molecules into smaller molecules. This releases a condensable hydrocarbon mixture, some combustible gases, and a coke-like residue. It is the liquid hydrocarbon mixture, the shale oil, and gases that are the most valuable.

This precious oil shale resource is one of the nation's most extensive and is very accessible. (See Figure No. 1) In southeastern Indiana the shale "crops out" in Floyd, Clark, Scott, Jefferson, Jennings, Jackson and Bartholomew counties. Here the shale dips to the southwest at 20 to 30 feet per mile and is at a depth of more than 4,000 feet in Posey county. Continuing north, in Johnson, Marion, Hendricks, Boone, Clinton, Tippecanoe, Benton, Carroll, White, Jasper and Newton counties, the formation underlies glacial material of varying thicknesses. Oil shale also underlies the glacial drift in far northern Indiana where it dips in a northeasterly direction of 20 to 30 feet per mile. This layer of oil shale is 60 to 80 feet thick in Porter County and thickens eastward to more than 170 feet in LaGrange and Steuben counties. This interval is, however, covered by glacial deposits up to 450 feet thick and in some areas it is covered by younger strata as well as glacial material.[3]

If all the oil shale of the state could be processed, the estimated potential is greater than 40 billion barrels of oil.[4] In comparison, the proven oil reserves at Prudhoe Bay-Alaska, where the famous Alaskan pipeline began, are about 10 billion barrels of oil. In a practical sense however, Indiana will be able to develop only a portion, perhaps 25%, of its shale reserves in the foreseeable future.

The most accessible and richest oil shale deposits in Indiana lie in Jefferson, Clark, Scott, Jennings, Jackson and Bartholomew counties. Here the oil shale lies close to the earth's surface and the area is not heavily populated. It is this location where much interest and several studies have been instituted. The anticipated yield of oil per ton of oil shale in this region range from five to eighteen gallons according to Fischer Assay.[5] Although these figures are lower than those obtained from western oil shale, significant quantities of coke, high-Btu gas, and steam by-products can also be generated by retorting processes.

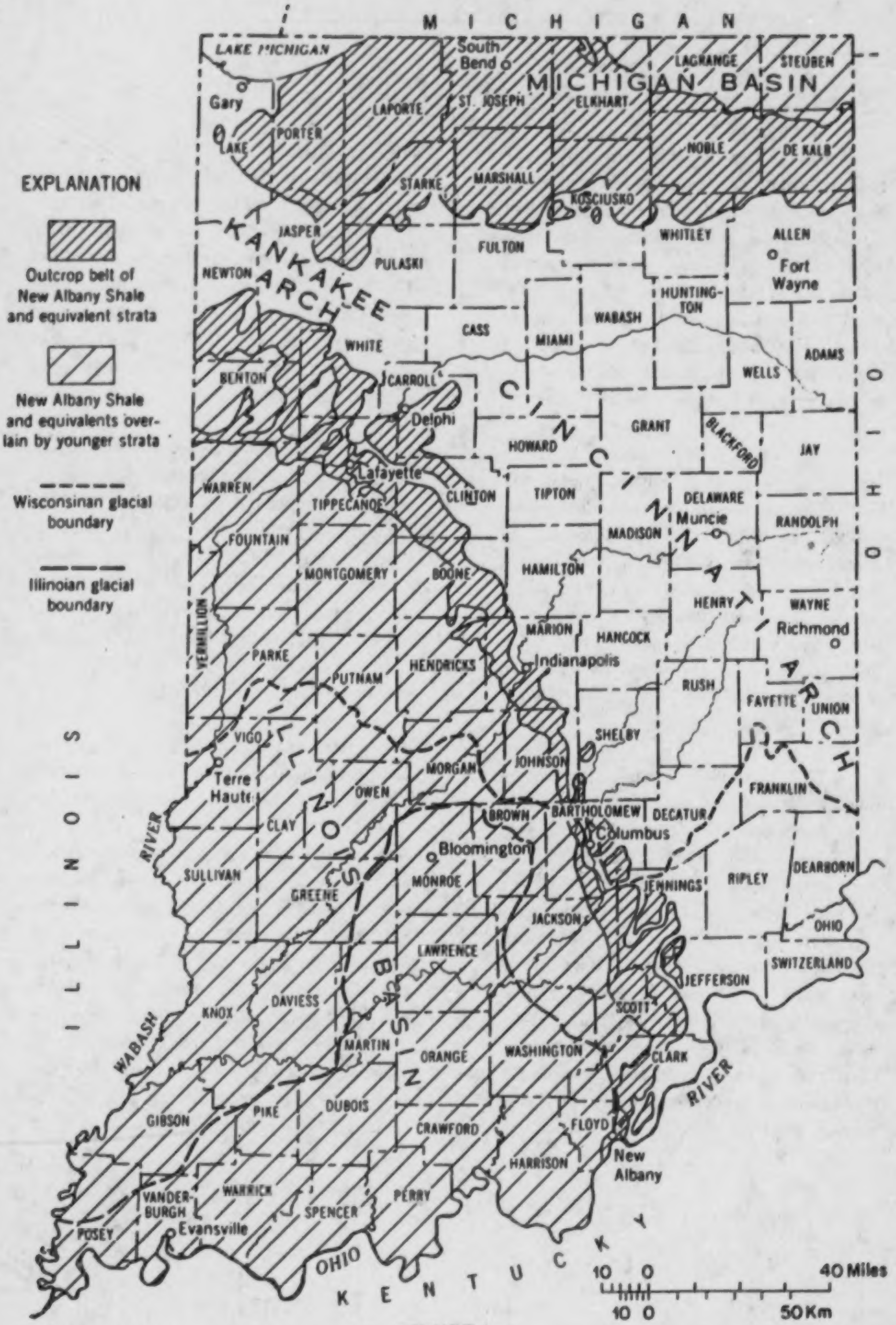

EXPLANATION
Outcrop belt of New Albany Shale and equivalent strata
New Albany Shale and equivalents overlain by younger strata
Wisconsinan glacial boundary
Illinoian glacial boundary
MICHIGAN
LAKE MICHIGAN
MICHIGAN BASIN
KANKAKEE ARCH
CINCINNATI ARCH
ILLINOIS BASIN
ILLINOIS
OHIO
KENTUCKY
WABASH RIVER
OHIO RIVER
South Bend
Gary
Fort Wayne
Delphi
Lafayette
Muncie
Richmond
Indianapolis
Terre Haute
Bloomington
Columbus
New Albany
Evansville
LAKE
PORTER
LAPORTE
ST. JOSEPH
ELKHART
LAGRANGE
STEUBEN
NOBLE
DE KALB
STARKE
MARSHALL
KOSCIUSKO
JASPER
NEWTON
PULASKI
FULTON
WHITLEY
ALLEN
HUNTINGTON
WABASH
MIAMI
CASS
WHITE
BENTON
CARROLL
ADAMS
WELLS
GRANT
BLACKFORD
JAY
HOWARD
TIPTON
CLINTON
TIPPECANOE
WARREN
FOUNTAIN
MONTGOMERY
BOONE
HAMILTON
MADISON
DELAWARE
RANDOLPH
VERMILLION
PARKE
PUTNAM
HENDRICKS
MARION
HANCOCK
HENRY
WAYNE
RUSH
FAYETTE
UNION
VIGO
CLAY
OWEN
MORGAN
JOHNSON
SHELBY
FRANKLIN
DECATUR
BARTHOLOMEW
BROWN
MONROE
SULLIVAN
GREENE
JENNINGS
RIPLEY
DEARBORN
OHIO
JACKSON
LAWRENCE
SWITZERLAND
JEFFERSON
SCOTT
KNOX
DAVIESS
MARTIN
ORANGE
WASHINGTON
CLARK
GIBSON
PIKE
DUBOIS
CRAWFORD
FLOYD
HARRISON
POSEY
VANDERBURGH
WARRICK
SPENCER
PERRY
10 0 40 Miles
10 0 50 Km

FIGURE 1

RECOVERY TECHNOLOGIES

Long ago, Indians of the mountainous west accidentally found that a certain marlstone would burn, so they threw chunks of it on their campfires. Later, some settlers in the region happened to use the marlstone to build their fireplaces, only to find that their fireplaces caught fire.[6] Most of today's methods of producing shale oil involve this heating process. One method mines shale and puts it through the heating process above ground. This is a conventional way of recovery, a familiar process used in such industries as copper refining and steel making. Another, newer method breaks up the shale while it is still in the ground and heats it in place (in situ).

CONVENTIONAL RECOVERY

Conventional methods of recovering shale oil consist of four basic steps: mining the shale; crushing it to the proper size for the retort vessel; heating the shale in the retort to release the oil; and refining the oil to bring it up to a high-quality product.

In Indiana, area mining is more suitable and less expensive than underground mining and initially it will be used almost exclusively. It is anticipated that area mining techniques very similar to those used in Indiana coal mining will be used.[7] The diagram in Figures 2A,B,C,D,E,F illustrates the mining and reclamation operations typical in Indiana coal mining.[8]

In area mining, the shale overburden is blasted loose and carried to a stockpile. It is later used to cover the spent shale. Then the exposed shale is reduced to rubble by explosives or is broken by bulldozers and taken to the crushing plant by truck or conveyor belt as in underground mining. As the overburden is removed in successive stages, spent shale and overburden are returned to the pit, topsoil is replaced and the land is revegetated.

Once delivered to the crushing plant, broken shale is crushed into still smaller pieces. The size depends on the particular heating process that produces oil from the shale.

The crushed shale is then fed into a closed retorting vessel and heated to a high temperature between 800°F. and 1000°F to decompose the kerogen. About 75 percent of the organic carbon is released from

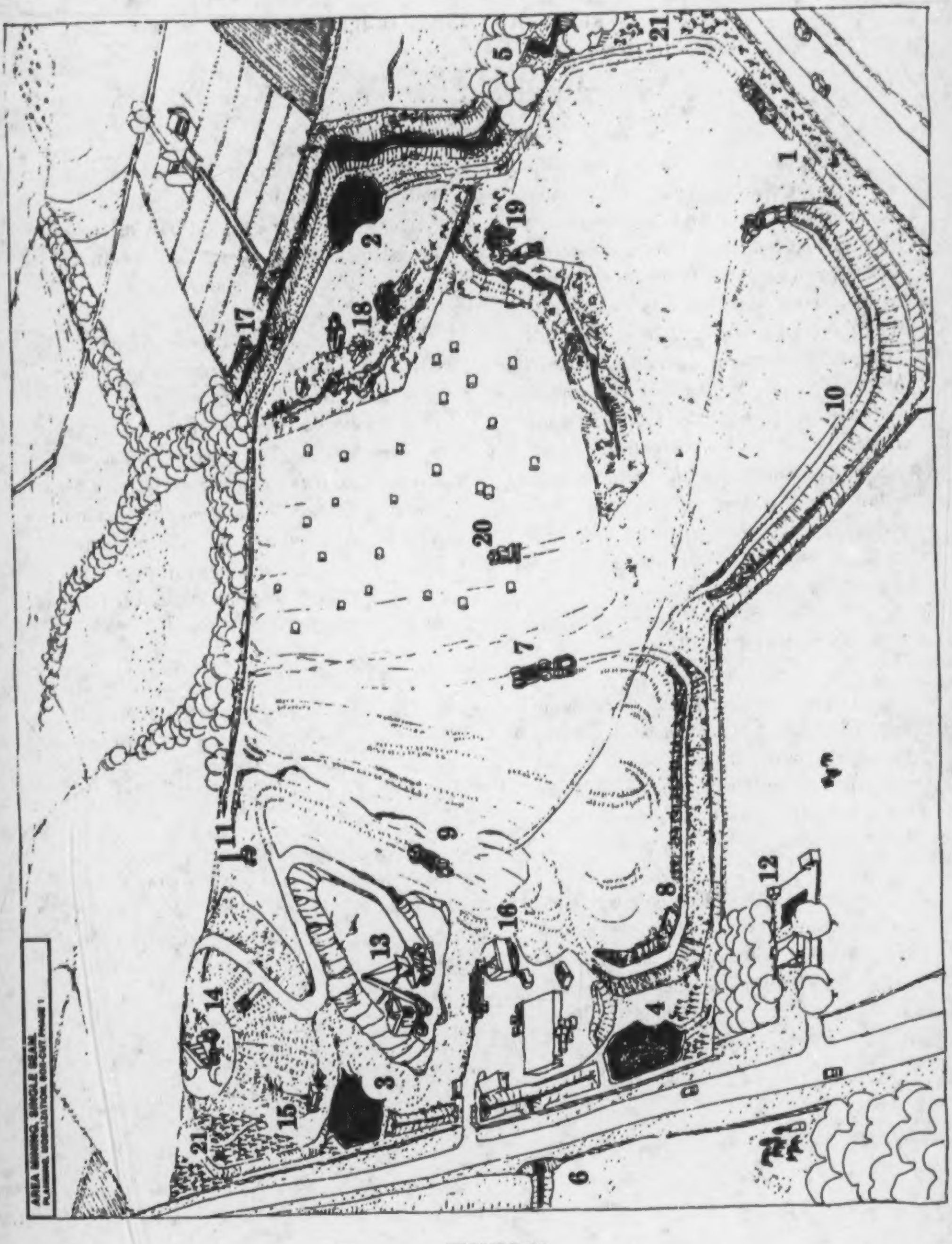

AREA MINING, SINGLE SEAM,
PLANNING, MOBILIZATION, BOX-CUT (PHASE I)
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FIGURE 2A

AREA MINING, SINGLE SEAM.

PLANNING, MOBILIZATION, BOX-CUT PHASE 1

If area mining is carefully preplanned and carried out in an orderly way, it is usually feasible to restore land to its original productivity within a short period and to minimize the impact on surface water and groundwater during and after working.

It is also possible to plan contemporaneous reclamation operations to occur steadily as mining progresses without incurring large increases in earth-moving costs. The importance of avoiding the double handling of overburden to the economics of area mining is recognized. However, it may be necessary to rehandle much of the overburden taken from the first box-cut in order to fill the final void and to eliminate the highwall. In cases where there is excess of fill in the site [816.105] it may be possible to place much of the overburden from the first box-cut permanently and avoid the need to double handle it as backfill for the final void.

The control of surface water on area mine sites is usually much easier than on contour mines. Points at which drainage from the site is discharged can be minimized. In the illustrated example drainage and overland flow is directed around the edge of the permit area in diversions to sedimentation ponds before discharging into receiving waters.

When the site is "prime farmland" the special performance standards in Part 823 apply. Whether or not the site is prime farmland is determined during the application process [779.27]. This Section contains a list of conditions, any one of which will result in the land not being classified as prime farmland. One important condition is that the Soil Conservation Service soil survey has not designated any soil map units as prime farmland.

Probably the major difficulty posed by the new Regulations for the small surface mine operator will be the greater amount of machinery required and the precision with which the operation must be planned to avoid delays. The requirement for contemporaneous reclamation will increase the importance of scrapers in the operation, and the requirement to transport box-cut spoil (to eliminate depressions and the highwall) will necessitate a large number of haulage trucks.

The Small Operator Assistance Program provides assistance for the small operator during the application process, notably with the analysis of overburden from core samples and assessment of the impact of the proposed mining activities on surface and groundwater [Part 795]. In spite of this assistance, the operator will be well aware of the need for careful preplanning of area mining operations if the requirements of the Regulations are to be met.

OPERATION		REQUIREMENT OF THE REGULATIONS*		DATA SHEET	
KEY	DESCRIPTION OF OPERATION	SECTION	REQUIREMENT	SHEET TITLE	NO.
(NOTE:	Numbers in text refer to illustration opposite.)				
1	Diversions to convey overland flow around the edges (1) of the site both to minimize interference with mining, and to reduce contamination of stormwater have be constructed.	816.43	"Overland flow . . . and flow in ephemeral streams may be diverted away from the disturbed area by means of temporary or permanent diversions." Temporary diversions to be designed for a 2-year storm.	Stream diversions. Overland flow and ephemeral streams.	6.4
2-4 5,6	Flow from these diversions pass through three sedimentation ponds (2,3,4) prior to discharge from permit area (5,6). These ponds must be constructed before disturbance of the site.	816.42(a)(1) 816.46(a)(1)	"All surface drainage from the disturbed area . . . passed through a sedimentation pond." "Sedimentation ponds shall . . . be constructed before any disturbance of the . . . area to be drained into the pond."	Sedimentation Ponds	6.3
7 8	Topsoil is being removed by scraper (7) and stockpiled (8). Topsoil beneath the spoil dump (14) was also removed.	816.21 816.22 816.23	Topsoil: General Requirements. Topsoil: Removal. Topsoil: Storage.	Clearance of vegetation and removal and storage of topsoil	6.6
9 -10	Unconsolidated (drift) overburden is being removed by scraper (9). Subsoil is being stockpiled (10) and the rest is being used to cover consolidated overburden on the spoil dump (14).	816.22(d)	"The B horizon and portions of the C horizon . . . shall be segregated and replaced as subsoil if the regulatory authority determines that . . . [it] is necessary."		
11	Drilling rig (11) drills consolidated overburden which is then shot.	816.62	A resident or owner of a dwelling within ½ mile of the permit area may request a pre-blasting survey to be carried out.		
12 13 14	Dwelling with a water supply well (12). Shovel digs first box-cut (13). Spoil is transported by dump truck to spoil dump (14). This is graded with maximum slopes of 1v:2h and covered with subsoil.	816.101	Box-cut spoils will largely have to be transported to the final cut. However, the RA in this case is permitting some of the box-cut spoils to be placed permanently and the left-hand slope of the spoil dump has been topsoiled and planted.	Temporary Spoil	6.7
15	A hydroseeder (15) applies seed and fertilizer to the temporary spoil mound (14) and to the stockpiles of topsoil and subsoil (8,10).	816.23(b)	"Stockpiled materials shall be . . . protected from wind and water erosion. . . ." Protection is usually accomplished by seeding with a cover crop of annual and perennial species.	Cover Crops.	7:11
16	Dragline assembly (16) is in progress. Construction of office and maintenance yard is complete.	816.150- 816.155	These Sections contain performance standards for Class I roads which will apply to the area here and to the access to the public road.	Haul Roads.	6:2
17	The stream has been diverted permanently (17). The channel has been graded and and constructed to reflect its natural character. The design standards for permanent diversions are more stringent than for temporary diversions, but the latter must be restored.	816.44(a) 816.44(b)(2) 816.44(d)	Flow from perennial streams . . . may be diverted only with the approval of the RA. Permanent diversions must be designed to carry flow from a 100 yr/24 hr precipitation event. The natural riparian vegetation and other natural characteristics of the stream should be restored.	Stream diversions: Perennial and intermittent streams.	6:5
18 19	Logging and destumping (18) are in progress along the old stream channel. Slash from clearance is being chipped (19) for use as mulch.	816.22(a)	This Section requires that "vegetative cover that would interfere with the use of the topsoil is cleared from the areas to be disturbed."	Clearance of vegetation and removal and storage of topsoil.	6:6
20	Note that much of the permit area is still in agricultural production (20), in this case a crop of mulch hay being harvested under contract for use during restoration. A feature of area mining is that it allows the minimum area of the site to be disturbed at any one time. The new Regulations emphasize the importance of minimizing the area disturbed and of contemporaneous reclamation.	816.22(f)(1) 816.45(b)(1)	"The size of the area from which topsoil is removed at any one time shall be limited." . . . Disturbing the smallest practicable area at any one time during the mining operation."	Mobilization and mining operations: General.	6:1
21	The operator has planted trees (21) on some areas of the site which will not be affected by mining.		This action is not required by the Regulations.	Revegetation: Trees and Shrubs.	7:13

*Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.

FIGURE 2B

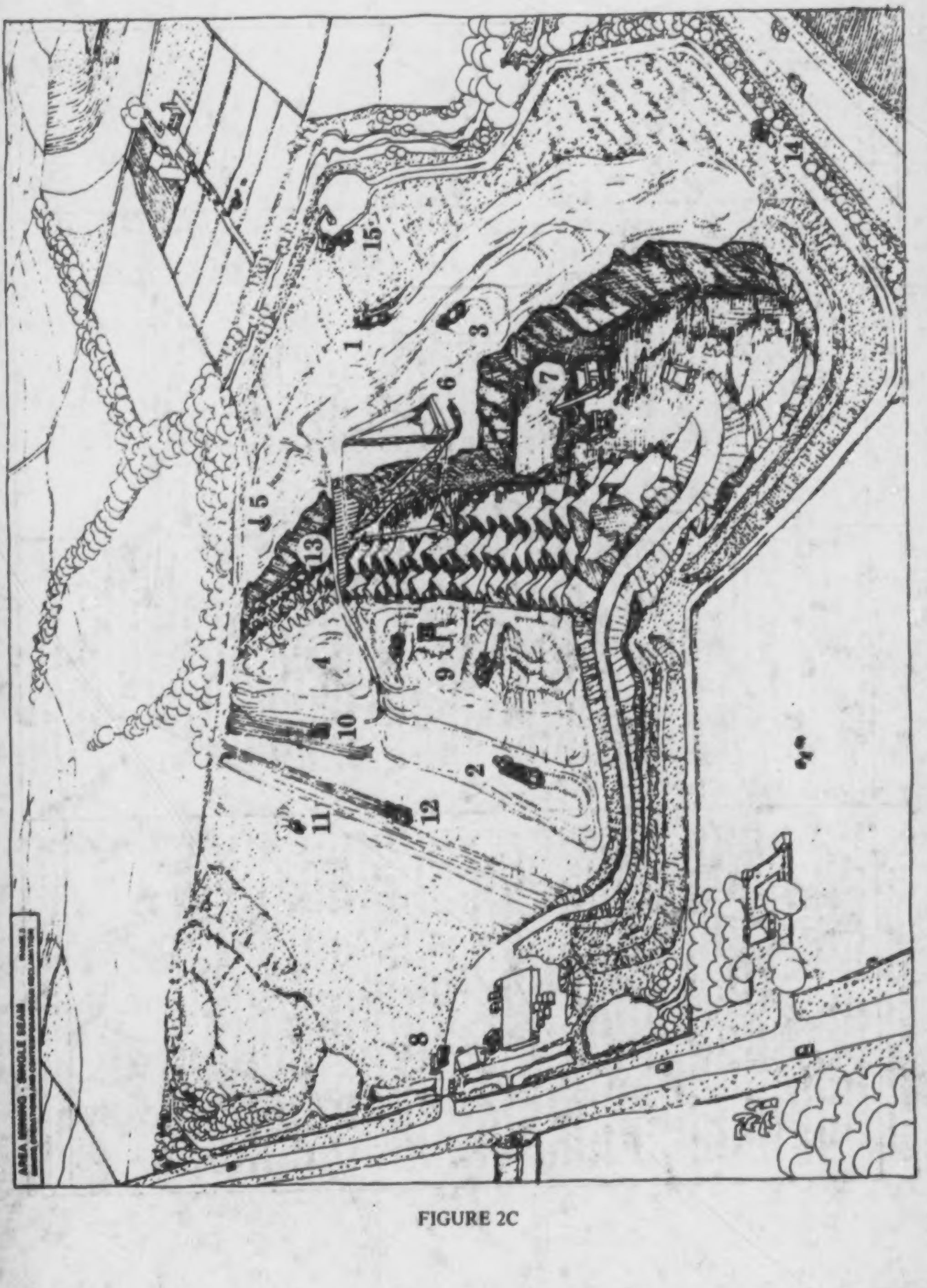
AREA MINING · SINGLE SEAM
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FIGURE 2C

AREA MINING - SINGLE SEAM

PHASE 2

MINING OPERATIONS AND CONTEMPORANEOUS RECLAMATION

Section 816.100 (Contemporaneous Reclamation) of the Regulations requries that "reclamation efforts, including. . .backfilling, grading, topsoil replacement and revegetation of all land that is disturbed by surface mining activities shall occur as contemporaneously as practicable with mining operations." The reclamation plan[780.18], required as part of the application process, must contain "a detailed timetable for the completion of each major step in the reclamation plan."

Section 816.101 requires that in area strip mining "rough backfilling and grading shall be completed within 180 days following coal removal and shall not be more than four spoil ridges behind the pit being worked. . ." In the illustrated example, the operator is ahead of this deadline.

Contemporaneous reclamation demands very careful allocation of machinery and preplanning, but the feasibility of contemporaneous reclamation in area mining is a feature which makes this form of mining more acceptable environmentally than most other forms of surface extraction. In the example shown, the operator has placed a temporary ramp across the pit to reduce the haul for scrapers carrying out contemporaneous stripping and replacement of unconsolidated overburden and topsoil.

Contemporaneous reclamation ensures that a minimum part of the permit area is disturbed at one time and therefore the hazards of erosion and water pollution are minimized. Note that in the illustration the land at the left of the site has already been regraded, topsoiled and revegetated. (Disturbance of the temporary spoil mound will occur at a later date.)

The temporary spoil mound and the stockpiles of topsoil and subsoil are protected from erosion by vegetation, and they will remain undisturbed until the backfilling of the final cut begins.

The diversions which carry overland flow from the site to the sedimentation ponds are kept mown in order that the resistance of the grass to erosion will not be reduced. One of the sedimentation ponds shown here is being dredged. This is required when sediment accumulates to 60% of the design sediment storage volume.

In order to clarify the method of working, some machines are shown more than once on this drawing. It is unlikely for instance that, on a site of this size, there would be 4 scrapers. Coaling may be done with a loader rather than a shovel as shown, and the operator will be able to find other unrealistic details in this example.

OPERATION		REQUIREMENT OF THE REGULATIONS*		DATA SHEET	
KEY	DESCRIPTION OF OPERATION	SECTION	REQUIREMENT	SHEET TITLE	NO.
	(NOTE: Text includes references to illustration opposite.)				
1 2	Scrapers remove topsoil (1) and redistribute immediately on the area being restored (2).	816.23(a)	"Topsoil . . .shall be stockpiled only when it is impractical to promptly redistribute . . . on regraded areas."	Removal and storage of topsoil	6:6
3 4	Scrapers remove subsoil and unconsolidated "drift" overburden (3) redistributing immediately (4) following rough grading of the cast spoil.	816.22(d) Part 823	The regulations do not require subsoil to be replaced separately unless the RA determines that it is necessary. In the case of prime farmland [Part 823] a minimum of 4' of soil material must be reconstructed.	Replacement of topsoil and cultivation	7:5
5	Drilling rig (5) bores blast holes, and shoots unconsolidated overburden.	816.61-816.68	Preblasting surveys may be required. All blasting must be between sunrise and sunset and a blasting schedule must be published.		
6	Dragline (6) digs and casts overburden onto previously mined area.				
7 8	Shovel (7) digs coal which is removed by road trucks which are weighed and cleaned (8) prior to entering the public highway.	701.5 816.150-816.176	Roads within the "immediate mining pit area" are not subject to the performance controls relating to haul roads in Part 816, but all others are.	Haul roads	6:2
9	Bulldozers carry out rough grading (9) of overburden followed by replacement of unconsolidated overburden by scrapers (4). Grading should approximate to general nature of pre-mining topography.	816.101(a)(3)	"Rough grading shall be completed within 180 days following coal removal and shall not be more than four spoil ridges behind the pit being worked. . ."	Rough backfilling and grading	6:10
		816.101(b)(1)	"All disturbed areas shall be returned to their approximate original contour."		
		816.102(a)	"Post-mining final graded slopes need not be uniform but shall approximate the general nature of the pre-mining topography.		
10	Crawler (10) scarifies the area prior to the replacement of topsoil (2) to reduce compaction of regraded spoil. On sloping sites, regrading operations should be parallel to the contour.	816.24(a)	"After final grading and before the replacement of topsoil . . . regraded land shall be scarified. . ."	Final grading Replacement of topsoil and cultivation	7:3 7:5
		816.102(e)	"All final grading, preparation of overburden before replacement of topsoil . . . shall be done along the contour. . ."		
11	Lime spreader (11) in operation and the necessary fertilizers are also spread.	816.25	"Nutrients and soil amendments in the amounts determined by soil tests shall be applied to the redistributed surface soil layer. . ."	Soil amendments: lime and fertilizer	7:6
12	Cultivation and seeding (12) takes place. These operations should be carefully timed and the seed mix chosen to ensure satisfactory growth. The area must be mulched unless the RA suspends the requirements.	816.111(b)	"All revegetation shall be. . .carried out in a manner which encourages a prompt vegetative cover. . ."	Revegetation: general Revegetation: herbaceous species Chemical stabilizers Cover crops Mulches	7:12 7:14 7:14 7:10 7:11 7:9
		816.113	"Seeding. . .shall be conducted during the first normal period for favorable planting conditions. . ."		
		816.114(a)	"Suitable mulch. . .shall be used. . ."		
12	A temporary ramp (13) across the working pit reduces the haul for scrapers involved in contemporaneous stripping and regrading. It will be mined through and then replaced by the dragline.	816.100	This facilitates the requirement of the performance controls for contemporaneous reclamation.		
14	Grass in the waterways is being mown (14) as are the embankments of the sedimentation ponds to ensure the erosion resistance of vegetation.	816.43	"Hydrologic balance: diversions and conveyance of overland flow. . ." This Section does not require diversions to be mown but this will help to prevent erosion.	Stream diversions: overland flow Grass waterways	6:4 6:4 7:4
15	Sedimentation pond is being cleaned out (15) because accumulations of sediment are reducing its effectiveness.	816.46(h)	"Sediment shall be removed from sedimentation ponds when the volume of sediment accumulates to 60% of the design storage volume.	Sedimentation ponds	6:3

*Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.

FIGURE 2D

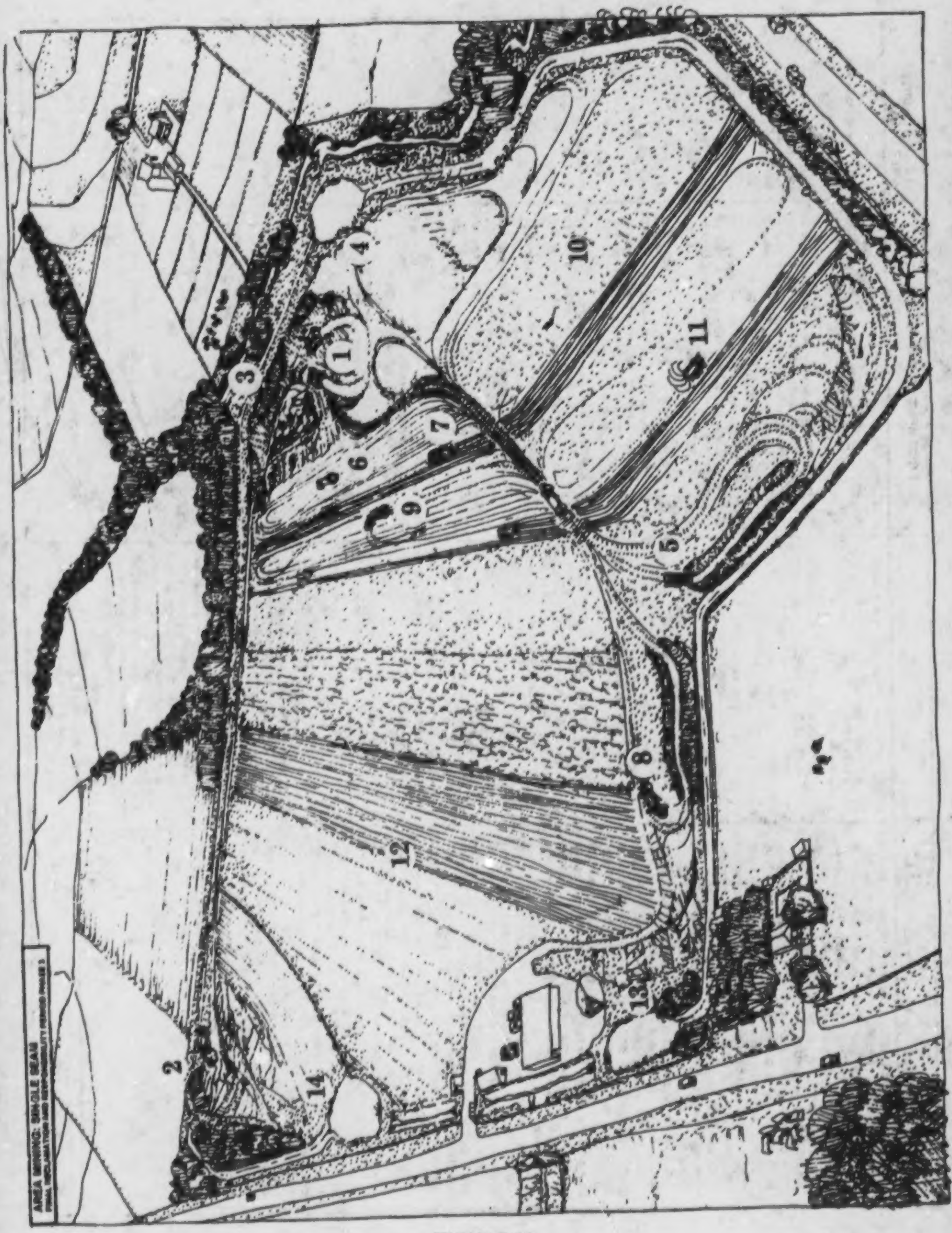
AREA MINING: SINGLE SEAM
FINAL RECLAMATION AND RESPONSIBILITY PERIOD PHASE 3
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FIGURE 2E

AREA MINING: SINGLE SEAM

FINAL RECLAMATION AND RESPONSIBILITY PERIOD PHASE 3

The Regulations require not only restoration of land to pre-mining productivity levels but also require that changes in quality and quantity of both surface water and groundwater are minimized [816.41].

Section 816.116 (b) (3) requires that the success of revegetation of areas to be used for cropland be judged in comparison to an approved reference area. Areas proposed for pasture [816.115] must have a grazing capacity equal to that of similar non-mined lands. The "period of extended responsibility" under the performance bond requirements of Subchapter J continues for a period of five years (in areas with more than 26" of rain which includes all areas covered by this Handbook). "Ground cover and productivity shall equal the approved standard for the last two consecutive years of the responsibility period" [816.116(b) (1) (i)].

When permit areas are 40 acres or less, reference areas as a standard for revegetation success can be replaced by standards set out in Section 816.116(d), and then only with the approval of the RA. The responsibility period and success standards are longer and more stringent on prime farmland [Part 823].

Note that in the illustrated example, a 2-acre lake (1) has been proposed as a farm pond for livestock. Under Section 816.49(a) "permanent impoundments are prohibited unless authorized by the RA." The proposal, however, is quite compatible with the proposed post-mining uses and would probably be allowed. Unless approval for this variance is obtained from the RA, Section 816.101(b) (1) requires that "all spoil shall be transported, backfilled and graded to eliminate all highwalls, spoil piles and depressions." This, in effect, would disallow any of the box-cut spoil remaining on the site of the temporary dump as has been shown (the wooded slope at the left will remain and the remainder graded to a gentle slope). However, the RA has discretionary powers to establish the final provisions for the disposal of box-cut and it is felt that, in this example, transportation of box-cut spoil to the final cut is encouraged in order that the requirements of 816.101(b) (1) for elimination of highwalls, spoil piles and depressions be satisfied to a reasonable degree without requiring rehandling of all box-cut spoil.

Note that 816.102 specifies that slopes need not be uniform but in "general nature" should approximate to pre-mining topography. With a bulking factor less than the ratio of coal to overburden, the final grades must be lower than in pre-mining terrain. The important consideration is to make sure that surface drainage is feasible across the site which would make uneven lowering of the site necessary and occasionally changing convex slopes to concave thus insuring surface drainage.

OPERATION		REQUIREMENT OF THE REGULATIONS*		DATA SHEET	
KEY	DESCRIPTION OF OPERATION	SECTION	REQUIREMENT	SHEET TITLE	NO.
(NOTE: Text includes references to illustration opposite.)					
1 2 3 4	Bulldozers carry out grading in the final void (1) which has been partially filled from the box-cut stock pile (2). Dump trucks (2) bring the loads of stockpiled overburden, partially back-filling the final void. The highwall, which is still just showing (3), will be completely eliminated. The depression (1) will remain in part to form a 2-acre lake for livestock also incorporating the sedimentation pond (4).	816.101(b)(1)	". . . all disturbed areas shall be returned to their approximate original contour. All spoil shall be transported, backfilled, compacted. . . and graded to eliminate all highwalls, spoil piles and depressions."	Rough backfilling and grading. Temporary spoil	6:10 6:7
		816.102(a)	"Post-mining final graded slopes need not be uniform but shall approximate the general nature of the pre-mining topography." Stockpiling and transportation of box-cut spoil to the final cut is encouraged.		
		816.49(a)	Permanent impoundments are prohibited unless authorized by the RA.		
5 6	Scraper removes stockpiled subsoil (5) for spreading on the backfilled cut (6). The area of this stockpile will require soil amendments, cultivation and seeding.	816.23(b)	Stockpiled materials shall not be disturbed until "required for redistribution on a regraded area."	Rough backfilling grading	6:10
7	A ripper pulled by a crawler tractor (7) scarifies the regraded area to reduce the compaction of regraded spoil prior to the replacement of topsoil (9). On sloping sites all regrading operations must be carried out parallel to the contour.	816.24(a)	"After final grading and before the replacement of topsoil . . . regraded land shall be scarified . . ."	Final grading	7:3
		816.102(e)	"All final grading, preparation of overburden before replacement of topsoil . . . shall be done along the contour . . ."		
8,9	Scraper returns to topsoil stockpile (8) after spreading (9). After removal, stockpile area must be cultivated and seeded. In the case of prime farmland refer to Part 823.	816.24(b)	"Topsoil . . . shall be redistributed in a manner that achieves an approximate uniform, stable thickness consistent with the approved post-mining land uses . . . prevents excess compaction. . . and protects topsoil from . . . erosion . . ."	Replacement of topsoil and cultivation	7:5
		Part 823	Topsoil requirements on prime farmland.		
10	After final grading and topsoiling, this area (10) was seeded with a temporary cover crop as the season was not correct for seeding the permanent species. It is now being cultivated and lime and fertilizer spread before seeding perennial species.	816.114(c)	"Annual grasses and grains may be used alone . . . or in conjunction with another mulch when the RA determines that they will provide adequate soil erosion control and will later be replaced by perennial species . . ."	Cover crops Soil amendments; lime and fertilizer	7:11 7:8
11	Lime and nutrients have been applied in this area (11) which is being cultivated and seeded. The area must be mulched after seeding unless the RA suspends the requirement.	816.113	"Seeding . . . shall be conducted during the first normal period for favorable planting conditions after final preparation."	Soil amendments . . . Revegetation: Herbaceous species	7:6 7:14
		816.114(a)	"Suitable mulch . . . shall be used . . . The regulatory authority may . . . suspend the requirement for mulch, if . . ." (see Regulations)	Mulches Chemical stabilizers	7:9 7:10
12	These areas (12) are being managed for grazing and cropland. "The period of extended responsibility" [816.116(b)] lasts for 5 years and begins "when ground cover equals the approved standard after the last year of augmented seeding, fertilizing. . .or other work. . ." Note that the 5-year responsibility period is applicable where annual precipitation is more than 26" (i.e., all areas covered by this Handbook). Elsewhere the period is 10 years.	816.115	When the approved use is pasture land, the grazing capacity must be approximately equal to that of "similar non-mined lands." This stand must be met for at least 2 years of the 5-year responsibility period.	Revegetation: General Revegetation: Herbaceous species	7:12 7:14
		816.116(b)(3)	For areas to be used for cropland, success of revegetation will be judged by comparison with an approved reference area. Crop production must be equal to or greater than that of the approved standard for the last 2 growing seasons of the responsibility period.		
13,14	Sedimentation ponds (4,13,14) are still in position as all reclamation in areas drained by them has not been completed.	816.46(u)	Sedimentation ponds shall not be removed until the disturbed area has been restored and the revegetation requirements of Sections 816.111-816.117 are met.	Sedimentation ponds	6:3

*Regulatory Program promulgated by the Office of Surface Mining of the Department of the Interior in accordance with the Surface Mining Control and Reclamation Act of 1977.

FIGURE 2F

the rock at these temperatures.[9] The retort is essentially a large kiln with a raw shale feeder hopper, various mechanisms that introduce heat to the shale, pipes to collect the oil and gas products, and a grate to discharge the shale residue that remains after the oil is produced.

IN-SITU RECOVERY

True in-situ recovery includes a central well, drilled into the bed of shale. One or more other wells are then drilled around the first well. Explosive charges are placed in the wells and detonated to fracture the surrounding shale. This fracturing process is necessary to create pathways or void spaces in the normally impermeable shale so that fluids may flow from one well to another.

Once the shale is fractured, it is ignited and compressed air is pumped into the combustion well to keep the fire burning. The hot combustion gases circulate along the pathways in the fractured shale, heating it to retorting temperatures (600°F o 1000°F) and producing gas and oil from the kerogen. Compressed air is then fed from other wells to the burn zone, where combustion is sustained by the carbon residue that remains as the shale is heated. The gas produced in the process is then withdrawn from the first or central well.

The oil and vapor produced by in-situ retorting condenses to a liquid in a sump at the base of the shale area and is then pumped to the surface. As feasibility studies are performed and technologies are perfected, the true in-situ process may eventually become practicable for Indiana. (See Figure 3)

In a "modified" version of in-situ recovery, about 30 percent of the lower portion of shale that is rich in organic material is first mined by conventional methods and retorted at the surface.[10] This leaves a void space beneath the remainder of the material. The shale is then fractured with explosives, filling the mined-out space with shale rubble. The rubble column is ignited, retorting the shale in place, as in the normal in-situ method, to produce gas and oil.

The oil from in-situ processing has the same characteristics as the oil retorted on the surface. It also has to be processed to remove impurities before being used as refinery feedstock.

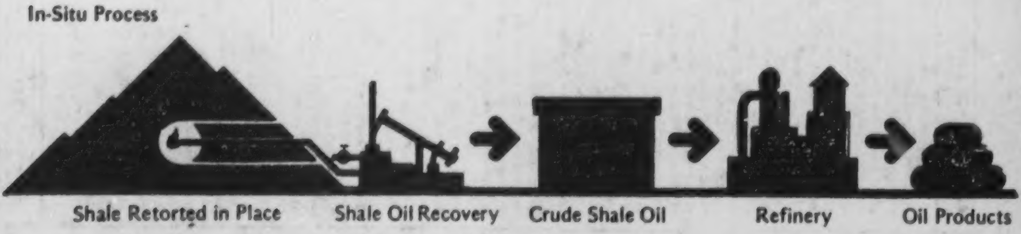

FIGURE 3

SPENT SHALE

The rock left after processing is called spent shale. Whether conventional or in-situ recovery is used, the inorganic material in the shale remains after the oil is removed. This amounts to about 85 percent of the total weight of the shale.[11]

Utilization of spent shale depends on experiments to see if it is harmful. Experiments have been conducted on spent shale utilization by some companies in Indiana. One possible use may be as a boiler fuel as there is usually enough carbon left after processing to reburn. If spent shale proves harmless some of it can be used in fill for roads. Until production of a uniform product by some process makes spent shale available for experimentation, predictions of use are not reliable. Because of the large volume of spent shale that will be available, most of it will be returned to the mine as fill.

OTHER SHALE PRODUCTS

Some gas produced in the retort and some in-situ recovery methods have economic heating value. This gas can be processed relatively inexpensively to provide on-site electric power for mining, retorting, and refining. It can also be treated to become high quality pipeline gas suitable for other industrial as well as residential consumption. Additional by-products should be able to be utilized, for example, anhydrous ammonia for farm fertilizers and high quality sulfur for industrial use. There may also be some precious metals made available. All these by-products could make our oil more economic.

THE ENVIRONMENTAL ISSUES, LAWS & REGULATIONS

The development of an oil shale industry, as with the development of any industry, is likely to impact upon the environment. Various groups including the federal government (Environmental Protection Agency, the Department of Energy), the State of Indiana, industry, and public action groups are closely monitoring such an environmental impact.

As yet, however, a number of unanswered environmental questions remain, i.e., water use, land use, air quality, and health effects.[12] Some questions can not be answered until a demonstration plant exists because the technologies to be used are too new. However, the affected ecosystems are becoming better understood as more research is accomplished. The scale of operations, even though small in Indiana, will allow prediction with relative certainty of what effects a large oil shale industry may have on the region.

The oil shale industry is developing production methods which should reduce adverse environmental effects, such as proper water use, land use, air quality and health effects. Public action groups are also contributing information on potential areas of disruption. Often there is overlap in this research and development but it does provide participants the opportunity to compare results and resolve technical differences. Out of this exchange may come solutions to problems associated with an oil shale industry. With this information, industry may develop in an economically and environmentally sound manner.

This cooperative approach is relatively new in the energy business. About 30 years ago little thought was given to the adverse effects of energy development. In this respect, oil shale development may serve as a precedent for future related energy developments. Because oil shale is the liquid "synthetic" energy resource closest to commercialization in Indiana, it may become the first to have been so thoroughly environmentally studied before it becomes established as an industry.

Generally, there are three areas the environmental researchers are interested in - water, land and air; a fourth, actually the combined effect of the other three is that of impact on human health.

WATER USE

Water is necessary for the processing of oil shale. Indiana is very fortunate, compared to western states with oil shale reserves because water is relatively abundant here, and should remain so in the future through proper management. Water is primarily required as a coolant for condensing the oil vapor. It will also be needed for dust control during mining and crushing, an essential aspect of air pollution control. Large quantities of water, either from rain or from other sources, will also be needed for land reclamation. Water needs are calculated per unit of net product and are determined by the type of retorting process, and upgrading process that is used.

Indiana's Stream Pollution Board, of the State Board of Health, and the U.S. Environmental Protective Agency have sufficient laws and regulations on the books to cover most major concerns about water at this time. The Division of Energy Policy in the Indiana Department of Commerce is also working with several different agencies and universities who are conducting research studies on problems that may arise to make sure all areas of interest are addressed.

In Figure 4 examples of western shale wastewater processing is explained. These methods could possibly be used for eastern shale as well.

Wastewater

Process	Waste	Contents	Management Technique
Mining	Groundwater	Salts, traces of fluoride, lithium and barium.	Reinjection, evaporation ponds, treatment and surface discharge or use, use as process water, evaporation from processed shale.
Retorting	Retort wastewater	Organic acids, oil, amines, phenols, salts, and certain trace elements.	For surface retorts: recycle, evaporate from processed shale. For in-situ retorts: use evaporative ponds.

FIGURE 4

LAND USE

Indiana's oil shale industry developments are expected to be located in a part of southeastern Indiana where major metropolitan concentrations do not exist. Although oil shale underlies a major portion of the state, these southern areas of low population are most likely to offer the most economic recovery. This area would also benefit greatly from the additional revenues that would be generated.

Figure 5 gives examples of ways in which western shale solid waste is handled.

Solid Waste

Process	Waste	Contents	Management Technique
Mining	Overburden dust	Silica, lead mercury salts	Water suppression
	Shale dust	Inorganic salts, toxic metals, organic	Water suppression

FIGURE 5

The oil shale industry will most likely use surface mining initially to remove the oil shale in Indiana. This method does disturb the land, but only on a temporary basis. Nearly all of Indiana's surface-minable shale is in the southeastern part of the state. Much of this area is wooded or brushy and sustains little agricultural activity. The soils located there are generally characterized as shallow and relatively infertile. Near and adjacent to the area proposed for oil shale development lies twenty-five to seventy-five percent prime farmland. Such land can be protected and reclaimed under present regulatory control.[13] Some additional statutes could offer increased protection to these areas of concern, but regulation should be carefully considered before adoption. Too many controls on oil shale development would hinder it's potential to boost the state's economy.

LAND RECLAMATION

Land reclamation activities will include spent shale disposal, overburden removal and replacement, revegetation, and surface water management. The Indiana Department of Natural Resources, Division of Reclamation will generally oversee these processes.

The methods planned for the surface mining of oil shale in Indiana are those currently employed in coal mining throughout southwestern Indiana. Waste materials, such as spent processed shale and some overburden, will be buried deep in the mine pit to protect surface and groundwater supplies from possible leachates. Excess overburden materials will be disposed of in hollow fills.

Soil will be removed and stockpiled prior to mining. Soil removed from advanced mining areas will be transported directly to areas undergoing reclamation. Because soils of southeastern Indiana are relatively shallow, the volume of soil that can be saved prior to mining may not be enough to achieve good agricultural conditions through reclamation. Should this be the case, selected overlying shale layers may be used as soil supplements or substitutes. One research project will be the attempt to use spent shale directly for revegetation. Once soil is restored, standard methods of revegetation and surface water management will be used for achieving effective erosion control. A study conducted by the Division of Reclamation, to be released in the very near future, suggests that the existing statutes dealing with areas mined for oil shale are inadequate for sufficient reclamation. The study recommends that either significant changes be made to the existing law (IC 13-4-6) or that a completely new statute, dealing only with oil shale, be enacted.[14]

AIR QUALITY

Emissions from an oil shale mining and processing facility may include all of the priority air pollutants: sulfur dioxide, hydrocarbons, particulates, and nitrogen dioxide. Consequently, these facilities will be designed to meet strict emission standards through the operation of modern air pollution control equipment.

New oil shale retorting facilities will be subject to state and federal regulations under the Clean Air Act. Permits will be required to have a New Source Review and Prevention of Significant Deterioration permit (PSD). Essentially, all oil shale retort operations, including experimental (pilot) plants, will require the issuance of a PSD permit. Most of the region that could be directly affected by an oil shale industry currently meets the National Ambient Air Quality Standard (NAAQS), set to protect human health and welfare. PSD permits would require that preconstruction air monitoring be utilized. No emissions would be permitted if they would cause or contribute to an NAAQS violation.

The Indiana Air Pollution Control Division, Indiana State Board of Health, has recently stated that sufficient regulations exist in Indiana to cover all environmental concerns. Figure 6 suggests ways that Western Air emissions are handled and could be utilized in Indiana.

AIR EMISSIONS

Process	Waste	Contents	Management Techniques
Mining, transport crushing	Raw shale dust	Inorganic, salts, toxic metals, organic compounds	Water suppression
	Overburden dust	Silica, lead, and mercury salts	Water suppression
	Vehicle and equipment pollutants	Ash and soot, carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons	Standard pollution control
Retorting	Raw shale dust	Inorganic, salts, toxic metals, organic compounds	Water suppression
	Processed shale dust	Alkaline compounds, carbon, soluble salts, trace elements (e.g. arsenic), soluble organic substances	
	Fuel combustion	Ash and soot, carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons, trace organics	Standard indus- pollution control
	Evaporated retort water	Hydrocarbons, hydrogen sulfide, volatile & trace organics	Standard industrial pollution control
Upgrading	Fuel combustion waste gases	Ash & soot, carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons	Standard industrial pollution control
Waste treatment	Solid particle & gaseous pollutants	Sulfur dioxide, particulates (ash & soot), nitrogen oxides, hydrocarbons, carbon disulfide	Standard industrial pollution control

FIGURE 6

Many rules and regulations currently apply to the oil shale industry. These regulations include:

a) Air quality (purity, visibility, gas composition, prevention of significant deterioration (PSD)).

b) Water quality and quantity.

c) Solid waste, including hazardous and toxic waste disposal.

d) Occupational safety and health standards.

Federal, state, and local statutes govern these areas. In general, any development must pay heed to the National Environmental Policy Act (1969), the Archaeological and Historical Data Conservation Act (1974) and the Endangered Species Act (1973). The following illustrate legislative mandates:

- Air quality - Federal Clean Air Act
- Water - Clean Water Act; Safe Drinking Water Act
- Solid Waste - Toxic Substance Control Act; Resource Conservation and Recovery Act; Surface Mining Control and Reclamation Act.
- Health - Occupational Safety and Health Act; Federal Mine Safety and Health Amendments of 1977.

In general, the standards and regulations above pose no insurmountable obstacles to oil shale development. However, some uncertainty exists regarding the possible interpretation and implementation of the regulations, the usefulness of available technology, and the development of future technologies.

The major constraints are the air quality standards and regulations under which three classes of purity are defined:

Class I - Areas in which essentially no air pollution may occur.
Class II - Areas in which some pollution is allowed. The degree of pollution is determined by the standard of "prevention of significant deterioration" (PSD) and varies from area to area.
Class III- Pollution may occur up to certain specified levels.

Existing standards require oil shale facilities in Indiana to meet the PSD requirements, but due to the possible location of a new industry locating in southern Indiana, this should pose no problem.

SOCIO-ECONOMIC ISSUES

In the western states where some oil shale production has been located, the work force consisted primarily of imported workers. The personnel were imported because the oil shale development was in remote locations where cities and towns did not exist. The large oil companies had to spend substantial sums of money to build roads, utility structures, sewers, electrical lines and all the supporting facilities a town would need in a remote location.

Indiana, in contrast, has many good roads and towns with available workers to properly support the oil shale industry. Special training will be required for some, but many jobs may be filled by the existing work force in southeastern Indiana.

Some impact studies should be conducted to allow schools and other facilities in small towns to make any necessary changes for the population growth. The increased tax base and the boost to the local economy should allow the towns to handle the growth quite well.

HEALTH EFFECTS

Health hazards associated with the mining and processing of oil shale include: (1) Mine safety and health hazards; (2) Oil shale processing health and safety hazards; and (3) Health hazards resulting from off-site pollution of the environment.

Health and safety hazards associated with the mining of oil shale are similar to those associated with the surface mining of coal. Safety hazards would include falling rock and hazards linked with the operation of heavy equipment and electricity. Health hazards in surface mining are primarily controlled by restricting the level of dust inhaled by miners and by controlling noise levels in the mine.

A major health concern at any shale oil processing facility is the occupational exposure of workers to shale oil. Much research has been conducted to develop a synthetic fuels industry in this country in the 1950s and early 1960s. Union Carbide built a small coal liquefaction pilot facility at Institute, West Virginia, which operated between 1952 and 1962.[15] Many of the health hazards initially encountered in the industry can now be controlled through the enforcement of strict industrial hygiene procedures.

Because of the known carcinogenic properties of some components of natural and synthetic liquid fuels, research has been active in the field of processing these materials. Initial results indicate that synfuels derived from oil shale may have significantly less carcinogenic activity than similar products derived from coal. An exemplary laboratory involved in this work in the United States is the Oak Ridge National Laboratory (Schultz, et al. . 1981).

Although most of the health hazards associated with an oil shale industry are occupational by nature, off-site exposures could occur as a result of transportation accidents and mishandling of the raw products. To minimize the risk of such exposure, proper safeguards should be employed and adequate precautions taken.

PERMITS

The operation of an oil shale facility requires more than 100 permits and other regulatory documents from federal, state, and local agencies. These include operational permits requiring maintenance of the environment and protection of the health and safety of both workers and the general population. In addition, any commercial or industrial activity requires permits for construction (building codes), for use of temporary buildings, sewage disposal, and occupancy. Considerable time and resources must be committed to secure the major environmental permits and Environmental Impact Statements (EIS) that are required before operations can begin. These are, as required by federal acts:

- A Prevention of Substantial Deterioration (PSD) permit required by the Clean Air Act.
- A National Pollutant Discharge Elimination System (NPDES) permit required by the Clean Water Act.
- A Solid Waste Disposal permit required by the Resource Conservation and Recovery Act.
- A permit to test the effects of and to keep various records for, the handling of toxic substances as required by the Toxic Substance Control Act.
- An Environmental Impact Statement (EIS) as required by the National Environmental Policy Act.

The federal agencies that review and approve permit applications include the Environmental Protection Agency, the Department of Treasury, the Department of the Interior (i.e. Bureau of Land Management (BLM). United States Geological Survey (USGS)). the Department of Defense (i.e., Corps of Engineers), and the Interstate Commerce Commission.

Generally an EIS would not be required in Indiana. The EIS pertains only to western oil shale deposits in the public domain. The Department of Interior, BLM has authority in Indiana, but they are limited as generally restricted to the western states.[16]

RESEARCH & DEVELOPMENT

During development of processing technology for oil shale, concurrent development of environmental controls should be undertaken. Environmental effects would be minimized and costly retrofits to oil shale facilities should be avoided once commercial production is under way. This is the rationale for implementing the federally sponsored investigation of oil shale issues.

The Environmental Protection Agency (EPA) provides funds for internal research and research by other government agencies through the Office of Energy, Minerals and Industry (OEMI). This research is divided into two basic programs including the Process and Effects Program and the Control Technology Program.

The Process and Effects Program:[17]

- Characterizes the types of pollutants that would be expected, measuring the magnitude of pollution discharged, and finding ways to monitor and detect the source of those pollutants.

- Trace what happens to the pollution in the environment. Where does it go? How does it get there? Once it arrives at its final destination, has its form changed to become more or less toxic?

- Defines toxic characteristics. Is human health to be impaired? What part of the body is most susceptible to the types of pollution? What limits must be set to keep hazardous substances out of the environment?

- Determines the effects on the ecologies of the area that are disrupted by the industry. What are the atmospheric and terrestrial ecologies? What are their needs to sustain life? And what will the shale oil development impacts be?

Then . . .

- Combines all the consequences of the development into one total integrated assessment for the environment, social and welfare effects, costs/risks/benefits, and selection of alternatives.

Parallel to the Process and Effects Program, EPA research in Control Technology evaluates and helps to develop techniques to limit the adverse impacts that shale development could cause.

The Control Technology Program:[18]

- Investigates mining techniques to reduce the adverse effects of the extensive amount of mining that will accompany a commercial oil shale industry.
- Looks at ways to reclaim those areas that have been mined or used for spent shale disposal. This includes the research on revegetation of spent shale piles.
- Assesses the types of the technologies available to control water, air, and solid wastes.
- Measures effluents from the retorting processes.

Not all of the work is being done by EPA scientists or in federal research laboratories. State agencies, private industry, universities, and independent research contractors are all involved in finding answers relating to oil shale problems.

LEASING OF INDIANA OIL SHALE LAND*

The purpose of this chapter is to assist landowners with questions that may arise if an offer is made for their property or the underlying mineral rights. Because most landowners are not in a position to mine oil shale on their own, they must look to a developer, a group or a corporation, with the equipment, knowledge, and financial backing to do the job. The legal arrangement for the landowner and the developer to get together is through a lease.

The landowner who signs a lease becomes a partner in a business operation. In general, the landowner agrees to allow the lease holder to enter upon his land at any time to begin mining shale. In return, the landowner receives a payment or royalty that may be calculated as a percentage of the product marketed. Some leases may also use a flat rate of return.

Because the lease holder becomes a business partner, the landowner should investigate to become fully acquainted with the prospective partner. Terms of leases vary. Terms may be negotiated. Landowners should not sign a lease unless they are fully satisfied that their rights as landowners are protected. Above all, landowners are advised to seek the advice of a competent attorney.

LANDOWNER'S CONSIDERATIONS BEFORE SIGNING OIL SHALE LEASE

1. Every landowner would like to know the amount of oil shale existing on his property before negotiating or signing a lease. Unfortunately, this is impossible to determine without drilling a number of test cores. The Indiana Geological Survey, 611 North Walnut Grove, Bloomington, Indiana 47405, has information pertaining to the distribution and thickness of oil shale, and publications regarding geological studies. It is important to discuss with the leasing company the number of acres required for the leasing site, access roads, etc. The landowner should also be aware of the possible damage to the land from oil shale mining activities (such as soil compaction from heavy equipment operating on wet land, erosion at mine sites) and the reclamation plan.

2. Investigate the reputation of the leasing company. Several companies have been leasing mineral or oil and/or gas rights in Indiana, and none is required to be licensed, bonded, or approved by any governmental agency in order to lease land for oil shale. For this reason, landowners should ask the leasing company for several references. Landowners should call each of these references and ask questions about the company's integrity and techniques and past performance.

3. An attorney should review the lease. Before leasing land or rights, a landowner should have an attorney experienced in mineral leasing review the lease, and if necessary, negotiate with the mining company for changes. The cost of the legal fee may be small compared with potential problems that could develop if the landowner does not understand the lease or fully realize what the company is allowed to do. Landowners can save on legal fees by joining with neighbors to hire one attorney.

*See Footnote No. 19

4. Negotiate protective terms into the lease. Most oil shale companies ask landowners to sign printed leases which sometimes do not adequately protect the landowner. The terms of these leases are negotiable and a landowner should refuse to sign the lease if the leasing company flatly refuses to negotiate any terms in the lease. The landowner may strengthen his bargaining position with the oil shale company by negotiating with a group.

5. Don't sign only because the neighbors signed. Landowners should never sign a lease for the sole reason that neighbors have already signed with a company.

6. Tax considerations and planning. The taxation of oil shale interests and income is complex, and therefore landowners should consult a tax advisor before signing any lease. In regard to the federal income tax, one will be concerned with the depletion deduction, and ordinary versus capital gain income, as well as other tax considerations.

PROVISIONS A LANDOWNER SHOULD CONSIDER NEGOTIATING IN HIS LEASE

1. Duration of the lease. Leases are divided into two separate time periods. The first period, or primary term, is a set number of years during or before which mining must begin or delay rentals must be paid. Keep this primary term short, if possible no longer than one year, to ensure mining action. The secondary term of the lease generally lasts as long as oil shale is produced, and thus, the landowner should be aware that his relationship with the company may be a long term one. Keep in mind that development of a mining program takes years to accomplish in the form of leasing, environmental studies, mine designs, permits, and cooperative development with the local committees.

2. Protect the agricultural use of the land. Landowners should negotiate the following provisions into the lease to protect the agricultural use of the land.

a. Require the company to indemnify, save, and hold the landowner harmless from all claims, demands, and causes of actions stemming from activities undertaken by the company or its assignees. If possible, require the company to carry liability insurance as added security from such claims.

b. Indiana regulations require the mining company to "restore the surface as nearly as possible to the condition it was prior to the mining within three to five years from the date of completion," and requires the company to post a bond to secure this performance. Any improvement over state regulations must be in the lease. The provisions for reclamation of land should be similar to those in coal mining leases.

3. Royalties, rent, and bonuses.[20] Most leases provide for a rental until oil shale is produced, and then a royalty. Lease rentals of $1 per acre or much less were common 40 years ago and have been recorded in Indiana cases as far back as 1899. Much of southwestern Indiana was held by 10-year leases at 10 cents/acre rented from the late 1930s into the 1950s. Farmers should look at today's values and establish what they believe to be a fair figure for their farm. Lease rentals should be paid in advance each year or the lease should be terminated. The landowner might also ask for a bonus payment in the event that another landowner in his locality is receiving higher rental or royalty percentage. Lease rentals are based on projected economics and are tied more to the value of the resource than to the land itself. Oil shale 40 years ago was not even worth $1/acre. Five percent is the standard royalty paid in mining.

4. Access to books and records of mining company. The landowner should require reasonable access to the books and records of the mining company so that the adequacy of the royalties received, may be evaluated.

5. Pooling provisions. Leases may allow the mining company to "pool" or form a mining "unit" out of the lessor's land in combination with the property owned by adjoining landowners. The result is that when oil shale is mined from any part of the unit, all owners share in the proceeds in proportion to the amount of property they own in the unit. One should exercise caution in granting a company the unrestricted right to pool the leased premises, and in any event, be sure that he understands completely the effect of a pooling provision, (for example, it can serve to tie up many parcels of land owned by several persons and keep all of the lease from expiring instead of doing so for only a single tract of a single owner).

6. Notification of intent to assignment of lease. Require that the landowner must be given written notification of the assignment of the lease to another party.

7. Warranty clause. To avoid any possible litigation expenses, landowners should seek to delete any reference in the lease that infers they will warrant title to the land.

TERMINATION OF THE LEASE

Before terminating any oil shale lease, the landowner should consult an attorney regarding proper cancellation procedures. If the landowner desires to cancel his lease for failure to mine, he must not accept the delay rental payments, or else the lease cannot be terminated.

Further information: Indiana Consumer Protection Office 317/232-6330.

THE OUTLOOK FOR OIL SHALE DEVELOPMENT

A deposit of oil shale has recently attracted a great deal of attention in southeastern Indiana. The reason for this attention is that it increases the potential for Indiana to become less dependent on out-of-state and foreign energy sources in the future. At present, Indiana imports approximately 74 percent of its energy needs. With the proper development of oil shale in Indiana, our state may significantly reduce its energy imports.

Many square miles of southeastern Indiana have the potential to provide more than 10 million barrels of shale oil (see Figure 4). Most research groups, such as the Indiana Geological Survey and the United States Geological Survey as well as many other institutions, feel that various technologies are at the stage needing pilot plant operation to develop this resource in an economically and environmentally acceptable manner.

This industry has the potential to create jobs, to add to the tax base of local and statewide communities and additionally to reduce our dependence on foreign oil. The state is therefore working diligently with all concerned industries to meet this goal.

The development of the oil shale industry in Indiana will have the potential for changing the natural, economic, and social environments of southeastern Indiana. Although the state wishes to use all the energy resources effectively, it is equally important to assure that the land can be used for crops and recreation after the mining and reclamation have been completed. Careful planning is necessary to ensure environmental safety. The state will be directing its attention to several areas of interest, which includes water quality and quantity, land reclamation, air quality, and socio-economic impacts. The state could feasibly become involved in cooperative efforts to research these areas. Only with these impacts adequately assessed can the success of prospective new shale oil industry be insured.

So what is the outlook for oil shale? Perhaps the best word is uncertain. Both costs of production and sources for the large capital investments required are uncertain, but the competition from foreign oil is certain. The approach to oil shale development is now more cautious and the gains and gambles are being weighed more carefully. Nevertheless, oil shale development is not stagnant. Research into better and more efficient production processes is progressing, studies of environmental effects are underway, and, in general, there is guarded optimism in much of the industry. Perhaps, after being an "almost" industry for so long, oil shale will soon turn the corner into commercialization as a safe and environmentally sound industry.

[10] Same of Footnote No. 6

[11] Same as Footnote No. 9

[12] D. Willard "Correspondence Letters to Indiana Energy Resource Development Division" Spring 1983

[13] Additional studies are being conducted in this area, see Land Reclamation Section this publication

[14] Same as Footnote No. 7

[15] Hower, see Footnote No. 2

[16] Same as Footnote No. 7

[17] Same as Footnote No. 6

[18] Ibid . . .

[19] This entire section is based on ideas from "Oil and Gas Leasing in Indiana" produced by the Indiana Farm Bureau Inc. Please seek an attorney. These are only guidelines, and suggestions. Date Unknown

[20] Based on information supplied by the Indiana Farm Bureau; School of Public and Environmental Affairs, Indiana University; and Indiana Geological Survey Fall 83

FOOTNOTES

Figure 1	"Resource Assessment of the New Albany Shale (Devonian and Mississippian) is Southeastern Indiana" Preliminary Report by Nancy Hasenmueller Indiana Geological Survey
Figure 2ABCDEF	U.S. Department of Interior, "Small Surface Coal Mine Operations Handbook" 1980
	[1] N. Hasenmueller "Resource Assessment of The New Albany Shale Devonian and Mississippian in Southeastern Indiana - Preliminary Report." Paper by Indiana Geological Survey. Date Unknown.
	[2] J. Hower "Kentucky Oil Shale Development" Kentucky Department of Energy August 1981
	[3] N. Hasenmueller, Ibid . . .
	[4] Indiana Geological Survey Characterization Study of Indiana Shale Publication. Date Unknown.
	[5] N. Hasenmueller "Distribution, Thickness, Lithology, and Geochemistry of The New Albany Shale in Southern Indiana" Spring 1981
	[6] Myers, Dorsett, Parket, "Oil Shale and the Environment" United States Environmental Protection Agency. October 1977
Figure 3	See Footnote No. 6
	[7] Indiana Department of Natural Resources "Correspondence Letter with Jim Buck" June 1983
	[8] Jim Buck, Ibid . . .
	[9] Eastern Shale Research Corporation Assessment of Indiana Oil Shale Estimates via various processes. V. Carr. 1983 August 9
Figure 6	See Footnote No. 6

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Indiana Bureau of Mines & Mining, Terre Haute, IN 47807
Indiana Department of Natural Resources, Indianapolis, IN 46204
Indiana Department of Revenue, Indianapolis, IN 46204
Indiana Farm Bureau, Indianapolis, IN 46204
Indiana Geological Survey, Bloomington, IN 47405
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Kentucky Department of Energy, Lexington, KY 40578
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Testimony of Joseph A. McElwain, Chairman of the Board, The Montana Power Company

before the

Subcommittee on Energy Research and Development of the Senate Committee on Energy and Natural Resources

March 12, 1984

My name is Joseph A. McElwain. I am chairman of the board of the Montana Power Company. Montana Power Company is an energy company which serves as an electric and gas utility to the western two-thirds of Montana. In terms of the area served, the Montana Power Company is the second largest operating utility in the United States. We also have major coal mining operations in Montana, Wyoming and Texas that are under Montana Power Company's wholly-owned subsidiary, Western Energy Company. Western Energy, last year, mined approximately ten million tons of coal and by the late 1980's will be mining approximately twenty-four million tons of coal a year in the three states it currently operates in.

I am deeply appreciative of the opportunity you have afforded me to testify in favor of continued and adequate funding of the Department of Energy program for development of the coal-fired magnetohydrodynamics (MHD) technology.

Montana Power Company and Western Energy Company have been early pioneers of the conversion of coal to energy through the MHD process.

As an electric utility which relies upon coal for its major base load, we are strongly interested in the efficient utilization of our coal resources.

Since 1973 when we in the United States got the signal of our vulnerability to dependence upon foreign sources of energy during the Arab embargo, the Montana Power Company has been a strong advocate of internalizing our energy capability through the greater utilization of our vast coal resources. The

United States possesses over 35% of the known coal reserves of the world, some 450 billion tons. The states of Montana, Wyoming and North Dakota possess approximately 45% of that coal reserve, with Montana having approximately 120 billion tons.

If we are to truly attack the problem of energy vulnerability, we must do everything possible to utilize these vast coal reserves.

It is for this reason that we in Montana have become great advocates of the MHD conversion process. As a utility executive, I simply cannot be satisfied with the present conversion factor of coal to electricity of approximately 30 to 35% efficiency. This is particularly true when there is a technology such as MHD which offers an ability to increase that efficiency to 45 to 55%. The commercialization of this process, in my judgment, represents one of the greatest contributions that can be made to efficient utilization of our coal resources, as well as making good conservation sense. If we can raise our utilization factor of coal by even 50%, this makes a great contribution to not only our energy source supply, but also to the capability of transporting coal to its place of use because every ton of coal shipped, if MHD is commercialized, would render 50 to 75% more energy than it currently does.

MHD presents the only technology for the direct conversion of coal to electricity on the scene today that increases efficiency as well as meets environmental standards and goals.

MHD is a relatively simple conversion process which moves a hot conductive gas through a strong magnetic field which then causes current to flow in the gas. There are no moving parts which should allow the process to run for sustained periods of time. MHD has the highest potential efficiency of all the new coal-burning technologies; its combustion process inherently controls

SO_x and NO_x. The impacts of burning coal 50% more efficiently have tremendous benefits in reducing related environmental impacts through less mining, less transportation, less effluents. There are no technological break-throughs required to proceed with this promising conversion process. We are at the point where we need to prove its efficiency, economics and commercialization of scale. With all this potential and the possibility of lower cost electricity, I believe MHD warrants a definitive multi-year development program at adequate funding to progress toward commercialization at an early date.

As you are well aware, we have substantial problems to overcome before nuclear power becomes a continuing source of supply for our increased energy needs. This leaves our great coal reserve as the one reliable source of internally generated energy.

It is clear that coal must assume an increasing part of our national fuel mix. We all know how the coal window has enlarged versus the previously perceived nuclear option. But we have not been moving with dispatch in this critical area. In 1974, coal accounted for about 44% of the energy utilities employed to produce electricity. In 1980, that figure had grown by only 6 percentage points — to only 50% -- while the consumption of electricity had leaped 19%.

Looking just a few years into the future, the best forecasts indicate the demand for electricity will escalate 114% by the turn of the century because electricity is that blessedly versatile form of energy that can serve many needs. Coal could and should be used to generate more than 2/3 of our total electricity, assuming attractive economics and superior technology.

Yet without MHD or some unforeseen exotic technology, coal cannot be expected to assume its destiny in our energy mix. Only with the massive gains in efficiency, economics and environmental control offered by MHD can coal play its assigned part in the shift from primary reliance on shrinking oil suppliers to our relatively abundant coal reserve. Prolonging the life of our coal supply through the efficiencies of MHD suggests that we should follow a course that will bring about expeditious application of the promising technology.

Outside our country, there are active research and development programs for MHD in the Soviet Union, Poland, Yugoslavia, India, China, Netherlands, Australia and Japan. The Japanese, in addition to their own program, have expressed an active interest in possible participation with the United States in development of MHD. Can all of these nations, as well as many of our own scientists, be wrong about the potential of MHD? I postulate that if we do not pursue MHD research, we may one day be buying this technology from other nations. However, today we are the leaders in coal burning-MHD technology and in just a few years its viability can be proven.

The utilities are more interested today than ever before and rightfully so, for MHD is the only technology that has been meeting its milestones successfully. The dollars spent have brought significant advances in recent years in areas which at one time were considered show stoppers.

1) Channel life - has gone from seconds to minutes to 1300 hours testing and an extrapolated life of 8000 hours.

2) A 4800° F coal combustor has been successfully developed and tested by TRW at the 20 MW_t level and 90% slag rejection; with testing of a 50 MW_t level combustor underway.

3) High temperature air heaters have not been successful. The near term alternative is use of oxygen air enrichment at a 3 to 4% efficiency loss, while development continues.

4) Steam Bottoming Data is encouraging - Argonne National Lab has successfully used soot blowers to strip MHD-type ash from tubes and CFFF tests on SO_x and NO_x are well below EPA limits.

5) A super conducting magnet of 6.2 Telsa has been built and tested at Argonne National Laboratory.

6) A successful DC-AC inverter was developed by the Electric Power Research Institute and installed at the CDIF.

7) Spinoffs have occurred - atmospheric slag rejecting coal combustors - low NO_x combustors - high temperature heat exchangers - hot gas (plasma) research, etc.

The MHD Users Group made up of 26 member electric utilities comprises the Edison Electric MHD Task Force. This group represents the major utilities of the United States using fossil fuels. The utility industry complex is represented by the MHD Industrial Forum which includes utilities, utility component manufacturers, suppliers and engineering, design and construction firms. Several have no government MHD contracts, but see the potential of the technology.

All this is encouraging, but if MHD is to prove its commercial viability, an integrated proof of concept facility is needed. How do we get there? The major concensus is that the quickest and cheapest is to couple an MHD plant to a conventional coal-fired plant. A multi-year program, directed to a proof of concept facility, is essential if MHD is to come to fruition.

The Department of Energy's 1985 MHD budget request does have dollars for MHD and is a multi-year program. Both are very meaningful steps toward developing MHD. I am concerned that the program currently proposed does not meet the goals required to enlist strong industry participation. If the utilities and supporting industries are given the opportunity to comment and provide input to this DOE program, I believe a most logical and efficient program can be developed. The Department of Energy has expressed a willingness to do this and is currently scheduling initial meetings with both the utilities and industry suppliers.

Two of my major concerns with the proposed DOE program are:

1) The 80 megawatt thermal system is too small. The utility industry in the study completed for the State of Montana Department of Natural Resources and Conservation outlines a set of qualitative performance requirements which must be met before the utility industry could, with reasonable expectations, proceed with commercialization of the technology. Serious thought must be given to building a system large enough to address the varying levels of scale-up risk for the different components. The system must be large enough to provide confidence in extrapolation of the data to a commercial sized unit to the utility suppliers as well as the utilities. This confidence is necessary to establish the very important Industrial Base. The recent Congress requested study "Magnetohydrodynamics (MHD) Program Evaluation," May 5, 1983, by Gilbert/Commonwealth for DOE also recommends larger proof of concept plants, preferably as an add-on to a commercial steam plant. Montana Power Company has made an offer to participate with the government in such a retrofit. While some additional risks are involved to go from the present scale of testing to the larger facility, the resulting reduction in the testing program, in overall program costs, development time, and addressing scale-up questions in the development

stage, would seem to justify those risks. The concept of an integrated-system test is strongly supported by the utility industry. If a test at the 80 megawatt thermal level is an intermediate stage in an R&D program, there may be some justification for this additional step, however, as an end to the government program it will not meet the needs of the utilities, nor meet the government's goal of developing an adequate data base that will enable private industry to apply the technology commercially.

2) I believe the proposed funding of the 1984-85 budget is insufficient to accomplish the stated goals. The dollars are not sufficient to carry on a research and development program toward a significant proof of concept facility. The industry has contributed substantially in the past, but the proposed percentage of participation in cost-share is optimistic for a technology at this stage in its development and facing the very real risks involved in scale-up. In addition, the funds for the Phase I scientific research program appear to be applied to basic research activities which were the focus of the program in the early 1970's. The research needed is that which will support the engineering scale-up required at this stage of MHD technology development. If the Phase II integrated system is pursued at a scale larger than 80 MW_t, the current government test facilities could be used to generate the data necessary to design the larger sized components. Furthermore, the program, as outlined, does not take advantage of cost savings to the program which might be achieved through cooperative technical and financial exchange with other foreign MHD development programs. I believe the government and Congress

also needs to demonstrate its commitment to a multi-year cost shared program and its reliability as a responsible partner with the utilities and industry to generate sufficient participation. The MHD budget for 1985 should be in the 30 to 40 million dollar range for MHD to make progress.

My evaluation is that the budget program is a start in the right direction, and I am delighted to see a reversal of position in the Department of Energy. However, I believe the current MHD technology is to a point where we need to outline a multi-year program to reach a point where its commercial and economic viability will have been demonstrated. The concepts contained in S. 1278 or H.R. 4392 provide the more complete multi-year program to bring the MHD technology to the point it can be put into use in the utility industry. I strongly recommend that these provisions be considered in structuring the DOE program. Commitment to a multi-year program can produce results if Congress makes the commitment through authorizing legislation whose long-term promise transcends parochial interests and the immediate federal commitment to a broad range of budgetary stringencies. MHD offers our nation, its utility customers and its utilities exceptional opportunities to replace dwindling oil reserves with coal in our total energy mix; to conserve our lone abundant energy resource by making the most efficient possible use of coal; to burn coal in the most environmentally acceptable, efficient manner; to facilitate the ability of utilities to meet national energy goals, and to offer the user of electricity hope of genuine progress being made in combating the escalation of the price of that energy form. I believe continued support for MHD is an imperative in the context of the national interest. Thank you for your attention and consideration.

STATEMENT OF RALPH L. SMITH

CHAIRMAN, COMMITTEE ON ENHANCED OIL RECOVERY
VICE PRESIDENT, BARTLESVILLE AREA CHAMBER OF COMMERCE
Bartlesville, Oklahoma 74005

INTRODUCTION

A major national problem, becoming acute in certain states, is not being addressed. The problem is steadily declining domestic crude oil production with its attendant loss of local economic activity and detriment to our national security.

Despite a four-fold increase in real prices of crude oil in the past decade and a doubling of exploratory drilling, oil production in the contiguous states has declined 25%. The simple truth is that, without a significant change in these trends, the domestic petroleum extraction industry is dying, different only in time from steel, consumer electronics, and automobiles in increased reliance on imports.

Oil producing states, recently flush with economic vitality, will follow Appalachia and the heavy industrial states into economic stagnation, unemployment, high social service costs, and decreasing tax bases (severance and income) to deal with these problems.

The reality of this problem is underscored by the recent spate of proposed and actual oil company mergers. The major operators know that it is substantially cheaper to buy someone else's reserves than to find new reserves of their own. While this may benefit the companies' stockholders and a number of corporate lawyers and investment bankers, it adds no new reserves, decreases competition, increases already difficult pressures on credit markets and interest rates (and hence, probably inflation), and decreases state and Federal income tax revenues.

The only truly critical energy problem in the U.S. today is that we cannot domestically produce enough liquid transportation fuels to meet our economy's demands. Unless something significant is done -- and soon -- the gap between demand and domestic supply can only widen -- increasing the reliance on imports that lies at the heart of the nation's energy, economic, diplomatic, balance of payments, and military problems.

This dire prediction belies the fact that more than 300 billion barrels of crude oil will be abandoned in known U.S. reservoirs at the conclusion of conventional primary and secondary recovery. This is twice as much as has been and will be conventionally produced from these reservoirs. The remaining oil, unlike that produced by conventional means, exists in a very different state, trapped in the reservoir rock by a variety of complex mechanisms.

Producing a portion of this "residual oil" is the objective of enhanced oil recovery (EOR), a number of sophisticated, high-risk production technologies. EOR is the only approach that can offer the "significant change" described above -- the only way to offset or defer the otherwise inevitable precipitous decline in domestic crude oil production.

Enhanced oil recovery may also be able to offer a significant contribution to our strategic energy preparedness. Currently, there is a gap in plans to meet oil shortages of an intermediate duration (1+ years). Near term, acute shortages are covered by the strategic petroleum reserve now being accumulated. Long-term supply disruptions are addressed by alternative fuel projects. Both of these programs receive billions of Federal dollars annually in on- and off-budget outlays. This vulnerability to intermediate term shortages of transportation fuels can be addressed by EOR research.

These two aspects of EOR research are addressed in this statement:

- Its impact on local economies; and
- Its potential role in energy security.

BACKGROUND

Three major engineering/economic studies in the latter 1970s predicted that EOR could substantially offset or stop the decline in domestic production at prevailing crude oil prices -- provided that sufficient R&D was done to make these complex processes predictable and effective enough to permit operators to use them. None of these projections have been proven by time. Enhanced oil recovery has not responded to the significant economic incentives that have been provided. This lack of response is due to the absence of a fundamental understanding of the residual oil resource and the mechanisms for recovering it. The reason that the three earlier studies' projections have proven wrong is that the necessary research to produce this fundamental understanding has not been done.

A fourth major study, by the National Petroleum Council (NPC -- an industry advisory panel to the Secretary of Energy) will be released this spring. It also predicts EOR production in the 1-2 million barrels per day range within the next decade. However, it also presumes that the needed R&D will be performed, that it will be successful, and that the resultant technology will be applied.

Certain analysts, nearly all in Federal bureaucracies, have argued that EOR is currently commercial because some EOR is being produced. They have overlooked the fact that only ten U.S. counties with particularly favorable reservoirs account for essentially all EOR; Kern County, California, alone accounts for 61% of the U.S. total. The reservoirs of these counties are not typical of the full residual oil resource base. But, based on the misunderstanding by these analysts and the absence of testimony to the contrary, adequate, stable funding has not been provided for Federal EOR research.

Given this lack of understanding by our lawmakers, the absence of an organized oil-state coalition, the presence of well-organized coalitions for other fuels, and a variety of other institutional and political reasons, the nation's focus in energy research has been and continues to be on sources other than oil (e.g., coal, nuclear, electric, and synthetics). While each of these energy sources is important, they will not make a significant, cost-effective contribution to the transportation sector in this century. Displacing of liquid fuels is unlikely; petroleum burned by utilities -- today mostly coke -- accounts for only 7% of utility fuels. Through their rate-payer-supported research consortia, and friends in Congress, gas and electric utilities are lobbying hard for increased Federal research. At the present time, Eastern coal states and the electric power industry are proposing a five-year, guaranteed doubling of commitment to coal research. Gas interests are arguing for substantially increased funding for unconventional gas research.

By contrast, EOR directly addresses the central energy problem by increasing domestic production from known reservoirs, improving our response capability to import disruption, and holding the potential for restoring production to the domestic oil industry and the oil-producing states. Unlike the utilities, however, there is no petroleum research consortium or public coalition to carry the message.

Further, no witness appearing before the authorizing subcommittee stressed the need for R&D in EOR, while all of the other energy sources are extensively represented. This anomaly is similar to the absence of testimony on EOR last year and in most previous years from the industry, the affected states, or the research community. This does not mean that there is no recognition of the problem. The larger oil companies have invested heavily in EOR. However, as with mergers, their production decisions are based on existing oil economics, not long-term public needs. Most of these companies are involved in offshore and foreign exploration and with other, more predictable technologies to increase their reserves, some even at higher costs (e.g., off-shore Alaska). The issues involved in EOR are apparently too complex for the smaller producers or individual states to address effectively.

The results over the last two years were devastating reductions in EOR funding based on the incomplete understanding of the problem. This was done while essentially all other fossil energy research budgets were increased relative to Administration requests. The simple reason was lack of vocal support, generally based on lack of understanding of the problem and the potential.

The Administration has proposed an EOR research budget for $12.2 million for Fiscal Year 1985 (plus an additional $1.2 million for tar-sands, for a total of $13.4 million). While this is an increase over 1983 and 1984, it is much lower than earlier budgets, and it does not fully meet the most urgent R&D requirements. The proposed level permits only minimal research efforts by universities and National Laboratories, and no substantial cooperative arrangements with the states or industry. It does, however, meet the obligation to the defederalized cooperative agreement partner, the National Institute for Petroleum and Energy Research.

In our view, the Administration's request is too low by at least $6 million, even given current deficits. Adding these funds would permit full funding of the vital university and National Lab programs; permit more active cooperation with industry and the individual states; and support a full feasibility study of using EOR as an emergency resource. Our larger concern, however, is that history will be repeated: that in the absence of testimony or Administration emphasis, this authorization and appropriation process may cut this program even below the Administration's individual request. This cannot be permitted to happen.

If, given the problem of the deficits, fossil energy research budget reductions are necessary, they should not be in the area where the national and state problems are most acute -- petroleum -- they should be made where the problems are substantially less pressing. Our most critical problem is not how to burn coal or gas in utility boilers; it is how to sustain a vital domestic industry, support important state economies, and reduce reliance on and vulnerability to imports.

The attached briefing paper provides more details on the problem and the Federal R&D program in EOR.

THE ECONOMIC IMPACT ON THE STATES

The problem of declining oil production is becoming particularly acute in the major producing states. All, except California (assisted by thermal enhanced recovery of heavy oils) and Alaska (blessed with the largest field in the Western Hemisphere, which is itself about to begin to decline), have suffered significant decreases in production in the decade 1972-1982 (the latest years for which data are available), for example:

- Mississippi by 55%
- Louisiana by 45%
- New Mexico by 35%
- Texas by 29%
- Oklahoma by 24%
- Illinois by 21%
- Utah by 16%
- Wyoming by 16%

Essentially all producing states, including California and Alaska, have experienced declines in reserves. For ten producing states -- Oklahoma, Kansas, and nearly all states east of the Mississippi — more than half of 1982 production was from marginal, "stripper" wells, averaging only 2.9 barrels per day, obviously approaching abandonment. In response to price increases, domestic exploration has doubled but the average size of newly found fields has fallen dramatically. In aggregate, we are replacing with new reserves only about 22% of what we are producing.

Unlike the major, multi-national oil companies, the producing states can neither "merge" into new reserves nor "move on" to more promising exploration targets abroad. Nationally, the problem is yet one more declining domestic industry; at the state level it threatens severe economic disruptions.

In some states, the decline in oil production has already begun to cause serious economic problems. Oklahoma is a good example. Oklahoma's recent decline has been somewhat less than some of the other large producing states only because it began earlier and has benefited from prices and incentives to sustain production from marginal wells. In 1982, 64% of Oklahoma's production was from such "stripper" wells, with an average production of only 3.5 barrels per day -- clearly approaching abandonment. This decline (and the softening of oil prices) has forced the state to pass special "temporary" taxes and to reduce public services significantly. As taxes rise and services deteriorate, it will be increasingly difficult to attract the new industry needed to replace the rapidly declining Oklahoma oil industry. As Oklahoma's wells are abandoned, however, nearly two-thirds of its known oil -- 26 billion barrels -- will remain in known reservoirs. The only opportunity to sustain oil-related Oklahoma activity and to produce a portion of this oil is EOR. If enhanced recovery can be applied, the state may have "breathing room" of ten to twenty years in which to develop or attract new industry. Without EOR, economic stagnation is essentially inevitable. Oklahoma is not unique in this. All major producing states are, or will soon be, confronted with the same situation. The map on the next page shows how severe and widespread the problem has already become.

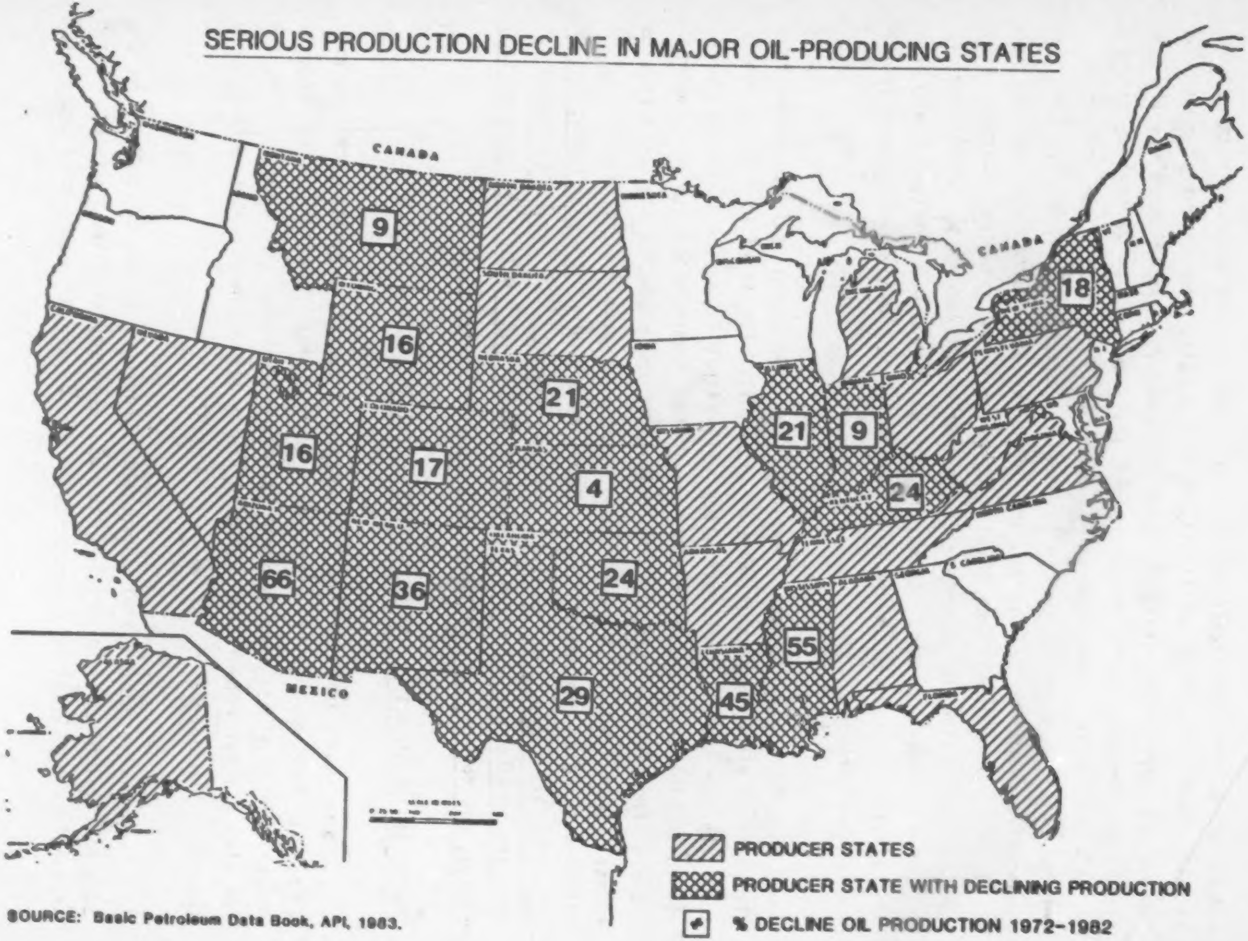
This is a public, not private, issue. Multi-national companies have alternative, often foreign sources of crude oil. EOR technology is currently too risky for smaller operators; they will simply leave the industry. Well-funded lobbies continue to direct Federal R&D toward other fuels. The real "losers" from those trends are the citizens of the producing states faced with higher taxes, reduced services, and decreased economic opportunity, (see attached table on employment in petroleum extraction). The only public option available is Federal EOR research and development. It should be funded at adequate levels and directed to work cooperatively with the universities, states, and the industry to assure the EOR opportunity is realized.

THE POTENTIAL IMPACT ON NATIONAL ENERGY SECURITY

As we have considered the issue of EOR research, a related idea repeatly comes up but apparently finds no institutional "home" in the Federal establishment, either Congressional or Administrative. The idea is that EOR can play a vital role in the nation's energy preparedness under certain, very specific conditions.

We observe the Federal government spending billions of dollars on the Strategic Petroleum Reserve (SPR) to cope with import disruptions of intense proportions but relatively short duration. We see allocations of additional

SERIOUS PRODUCTION DECLINE IN MAJOR OIL-PRODUCING STATES


CANADA
CANADA
MEXICO
9
16
16
17
21
4
66
36
24
29
21
9
24
55
45
18
PRODUCER STATES
PRODUCER STATE WITH DECLINING PRODUCTION
% DECLINE OIL PRODUCTION 1972–1982

SOURCE: Basic Petroleum Data Book, API, 1983.

billions of dollars for synthetic fuels to cope with disruptions of very long duration or permanent termination of imports. A gap exists in our preparedness strategy for disruptions of an intermediate duration (e.g., 1-3+ years), unless one includes the billions spent for the Rapid Deployment Force. As demonstrated in the attached White Paper, it appears that EOR, with appropriate planning and "pre-engineering," could fill this gap. Thus, there is the need for Congressional direction.

Note: EOR is neither an alternative nor a competitor of SPR, synfuels or the Rapid Deployment Force; it represents the complement of a continuum that is now incomplete and enriches the options available. The concept has not been further developed because EOR lies outside the mandate of DOE's emergency preparedness staff; conversely, emergency responses lie outside of the mission of DOE's experts in EOR.

The White Paper contains a detailed definition of the concept of "pre-engineering" and a qualitative analysis of the prospect for EOR to meet emergency requirements of 385 thousand barrels per day within one year and about one million barrels per day within two years. The analysis suggests that a relatively small number of highly important reservoirs could meet these requirements. If the "pre-engineering" needed to achieve this level of readiness were developed cooperatively with industry and the states, this could be a highly cost-effective complement to the nation's energy preparedness strategy while accelerating EOR applications in the absence of an emergency, thereby reducing overall vulnerability.

The analyses done to date, however, are only suggestive. The White Paper has been favorably reviewed by experts in industry and government. The comments to date argue that the concept has merit, but they also point up the need for more detailed engineering/economic analyses of the feasibility of the concept and an evaluation of alternative means for implementing it. A voluntary, industry-government (Federal and state) cooperative approach could well yield substantial benefits to the states, the nation, and the participating companies while working through basic market mechanisms.

Fortunately, the National Petroleum Council is currently completing an in-depth analysis of the potential of EOR under non-emergency conditions. Due to the intensive cooperation of the DOE Bartlesville Project Office (BPO -- the Federal successor* to the defederalized Bartlesville Energy Technology Center, who developed the White Paper), the reservoir data base and EOR process and economic models used by the NPC now reside on the BPO computer. This highly credible basis of data and models could be used to perform the needed preliminary feasibility and benefit-cost analyses. The first order questions are highly technical, relying on geological, technological, and economic assessments of whether EOR can actually meet specific targets for emergency production. The second set of questions pertain to how best to implement the appropriate program in collaboration with the states and industry, and the benefits and costs of various alternatives. These call for both policy and technical/economic analyses. Once these issues have been successfully addressed, the third-order questions of needed state or Federal legislation (if any) and appropriate programmatic guidance come to bear.

With the reorganization of the Department of Energy, consolidating the management of SPR with the Fossil Energy R&D function (which includes EOR), we believe that the time is appropriate to examine the detailed feasibility of EOR as a complement to the present emergency preparedness strategy.

Toward this end, we ask that the authorization process direct that the Secretary of Energy conduct a detailed feasibility study of the potential benefits and costs for EOR to contribute to an overall energy preparedness strategy. The funding for the in-depth study should be one million dollars.

The directive should explicitly request that the Secretary employ the reservoir data and models used by the NPC (or contemporary, updated versions of these) to conduct the study. The direction should include a report to the Congress within eighteen months of the appropriation. The report should include a detailed technical assessment of the feasibility of EOR in emergency preparedness, alternatives for implementing this concept (if technically feasible), an assessment of the benefits and costs of each alternative, and a recommended plan of implementation.

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* Not to be confused with the National Institute for Petroleum and Energy Research (NIPER), the non-Federal operator of the facility.

While we ask that you introduce this concept, we hope you will also seek to assure its inclusion in the appropriating legislation. We very strongly believe that EOR, as a complement to the nation's energy security posture, is an idea that has been overlooked. It is time to correct this oversight.

These two ideas are closely related. The cooperation with the states and industry, suggested as part of the R&D issue, could be accomplished in the context of efforts to "pre-engineer" and test sites for an emergency response. Conversely, the R&D program would benefit from the heavily instrumented, cost-shared field experiments that would be necessitated by a comprehensive EOR emergency preparedness strategy. Together, the two strategies hold vast promise for reversing the decline in Lower-48 oil production -- as tests yield results -- and success breads its imitators -- and for assuring reliable, cost-effective, peaceful options for import emergencies of intermediate duration.

What is needed now is far-sighted leadership of those who understand the problem, especially in the Congress. EOR research, with a coordinated use of EOR as an energy security fuel, will have significant, highly cost-effective benefits to the nation and to the producing states. Our Committee hopes you will see the urgency of this issue as we do and provide support of an adequate Federal EOR research and emergency preparedness program.

Thank you for joining us in this important national effort.

EMPLOYMENT IN PETROLEUM EXTRACTION INDUSTRY

		Pet. Production Decline 1972-82 (%)	1981 Jobs in Pet. Extraction	% Total Employment in Pet. Extraction (%)
1.	Alaska	NA	7,064	4.0
2.	California	NA	37,969	.3
3.	Colorado	17	25,104	1.7
4.	Illinois	21	7,300	.1
5.	Kansas	4	17,307	1.5
6.	Louisiana	45	94,721	5.6
7.	Mississippi	55	11,778	1.2
8.	New Mexico	36	16,328	3.0
9.	Oklahoma	24	92,100	6.6
10.	Texas	29	278,896	4.1
11.	Utah	16	5,915	.9
12.	Wyoming	16	22,008	9.1
	TOTAL U.S.	25	673,940	.7

Total Employment in (000)	1970	1975	1980	1981
Oil and Gas Extraction	270	329	560	686
All Mining	623	752	1027	1132
% OIL/ALL MINING	43.3	43.8	54.5	60.6

SOURCE: "Statistical Abstract of the U.S." -- Department of Commerce
"Employment and Earnings" -- BLS-Department of Labor

REVIEW
COPY

FEDERAL ENHANCED OIL RECOVERY RESEARCH:

Increased Understanding of the 300 Billion Barrel U.S. Residual Oil Resource and The Technologies to Produce It

INTRODUCTION

The steady, predictable decline in U.S. crude oil production — especially in the Lower 48 states — decreases domestic economic activity, employment and state and Federal taxes, while increasing balance of payments deficits and diplomatic, military, and economic vulnerability to import disruptions. Despite the private annual expenditure of tens of billions of dollars on exploration and production — $100 billion in 1984 — and a four-fold increase in the real price of crude oil, domestic crude oil reserves continue to decline.

Yet, more than 300 billion barrels of oil will be abandoned in known U.S. reservoirs after all conventional production techniques have been exhausted. This massive resource, called residual oil, is trapped or unreachable by conventional technology. Enhanced oil recovery (EOR), a series of sophisticated oil extraction processes, can produce a portion of this residual oil. It is one of the lowest cost options for slowing or reversing the decline in domestic reserves and production.

While a number of major incentives have been provided to stimulate EOR development and application, actual EOR production has never exceeded 5% of U.S. production and nearly all of our current EOR production comes from a very small number of highly favorable reservoirs. Among the most significant impediments to EOR production is our limited understanding of the residual oil resource and of the mechanisms that can displace and mobilize it.

Federal EOR research is designed to increase the understanding of the residual oil resource and the EOR technologies to produce it. As understanding increases, we will be able to predict better the performance of EOR processes in specific reservoirs, to increase the proportion of oil produced, to help stabilize domestic production, and to estimate future U.S. oil production rates more reliably.

This briefing reviews the problem of declining U.S. oil production, the opportunity of EOR to produce the massive residual oil resource, and Federal EOR research to generate vitally important knowledge to realize this opportunity.

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References 26-27

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
BARTLESVILLE PROJECT OFFICE

FEBRUARY 1984

FEDERAL ENHANCED OIL RECOVERY RESEARCH:

Increased Understanding of the
300 Billion Barrel U.S. Residual Oil Resource
and
The Technologies to Produce It

BRIEFING SUMMARY

THE PROBLEM: Domestic petroleum production is on a path toward steep decline despite much higher oil prices.

- This decline is detrimental to national interests:
  - The domestic petroleum industry is showing signs of following steel, consumer electronics, and automobiles toward reliance on foreign supplies.
  - Increased imports will reduce domestic employment, productivity, and economic activity.
  - Increased imports will reduce Federal and state tax bases, as other nations capture these economic benefits.
  - Increased imports will exacerbate balance of payments deficits.
  - Increased imports will increase vulnerability to import disruptions and international pressures from exporting countries and our trading partners.
  - Our national economic and military security demands a significant level of domestic petroleum production.
- Higher oil prices have increased domestic exploration and prolonged the life of marginal wells, but neither of these has nor can significantly offset the decline in petroleum production.

THE OPPORTUNITY: 300 billion barrels of known residual oil will be abandoned in discovered U.S. reservoirs after conventional production techniques have been exhausted.

- Residual oil is trapped by interfacial or viscous forces, or lies in parts of the reservoir that cannot be swept by usual means.
- Enhanced oil recovery (EOR) represents a number of processes designed to produce residual oil.
  - Future EOR production is highly uncertain, but EOR has the potential to maintain U.S. oil production near its current level, within current and near-term prices.
  - EOR is potentially the least-cost option for maintaining domestic production.

THE CONSTRAINT: Inadequate understanding of the residual oil resource and the basic mechanisms for its recovery constrain EOR production despite substantial economic incentives.

- Production from EOR processes increased only 9% between 1978 and 1982 despite a more than 200% rise in real oil prices and more than $4 billion in direct and indirect public incentives.
- Current EOR production is less than 5% of total U.S. production despite the initiation of more than 600 projects.
- Current EOR production is nearly all from uniquely favorable reservoirs:
  - Kern County, California, alone accounts for almost 61% of U.S. total EOR production;
  - Seven reservoirs account for half the 1982 U.S. total EOR production.
- Unpredictable performance, due to inadequate basic understanding of the residual oil resource and EOR processes, renders EOR unresponsive to market incentives.

TOWARD THE SOLUTION: A national research effort will increase understanding of the 300-billion barrel residual oil resource and the technologies to produce it.

- The Federal program has two closely integrated major components:
  - Basic Geoscience and EOR Process Research addresses critical uncertainties to improve fundamental scientific understanding of the massive residual oil resource and its recovery technologies.
  - Tertiary Oil Recovery Information System (TORIS) analyzes discrepancies between predicted and actual EOR field performance, projects the overall EOR contribution to domestic production, and assesses the potential impact of laboratory research.

- The program produces three types of improved understanding for three sets of users:
  - Private and public researchers: highly specific definition of the critical scientific uncertainties that limit understanding — accelerating the acquisition of knowledge leading to the development of efficient technologies to produce currently abandoned oil.
  - Private users of EOR: detailed understanding of the performance of specific EOR process designs in particular reservoir types — accelerating application of EOR technologies and, thus, domestic oil production.
  - Public and private policymakers: reliable projections of overall EOR production, which are now highly uncertain — improving the effectiveness of investment and policy decision making.
- As understanding and predictability improve:
  - Private industry will develop and implement the technologies for recovering residual oil;
  - Projections of domestic oil production will become more reliable;
  - Policymakers will be able to make better decisions relating to domestic oil production; and
  - Federal EOR research objectives will have been met.

Declining Domestic Crude Oil Production is Central to Energy, Security, and Economic Policy

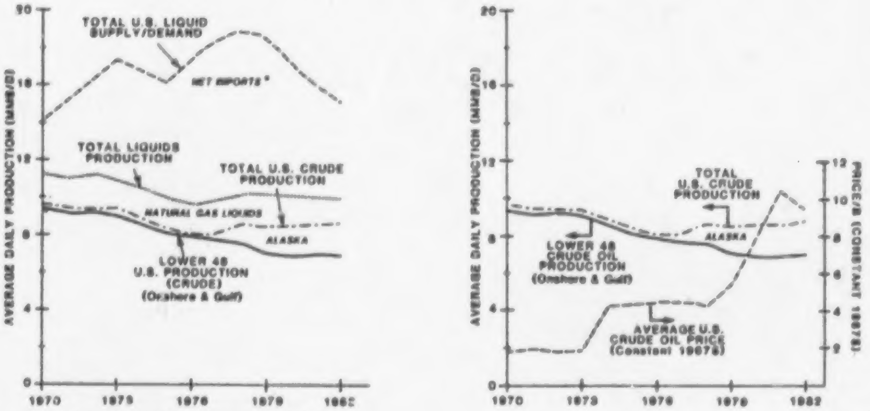
- Alaskan oil and natural gas liquids have sustained otherwise declining U.S. crude oil production:
  - Prudhoe Bay in Alaska — the largest oil field in the Western Hemisphere and a geological occurence unlikely to be duplicated — has provided time, but has passed its primary production peak and begun secondary recovery.
  - Natural gas liquids result from gas production — which has been relatively constant — and depend on gas, not oil, economics.
  - Lower-48 production has decreased by more than one-fourth since 1970.

- The gap between U.S. production and demand has been met by imports:
  - Demand peaked at nearly 19 MMB/D in 1978 — with 44% supplied by imports.
  - From 1978 to 1982, demand declined by 23% due to conservation and economic slow down, but demand — and imports — have begun to rise with the 1983 economic recovery.

- The one-fourth decrease in Lower-48 crude oil production has occurred despite a nearly 4-fold increase in real prices for domestic crude.

- Declining domestic production has important implications for U.S. energy, economic, and national security policies.

U.S. Liquid Fuel Supply, Demand, and Prices



* Includes adjustments for changes in stocks processing gains and losses: unaccounted for and lost crude exports.

SOURCES American Petroleum Institute, 1983, Interstate Oil Compact Commission, 1983.

Sharp Decline in Lower-48 Production is General Across Nearly All States and Regions

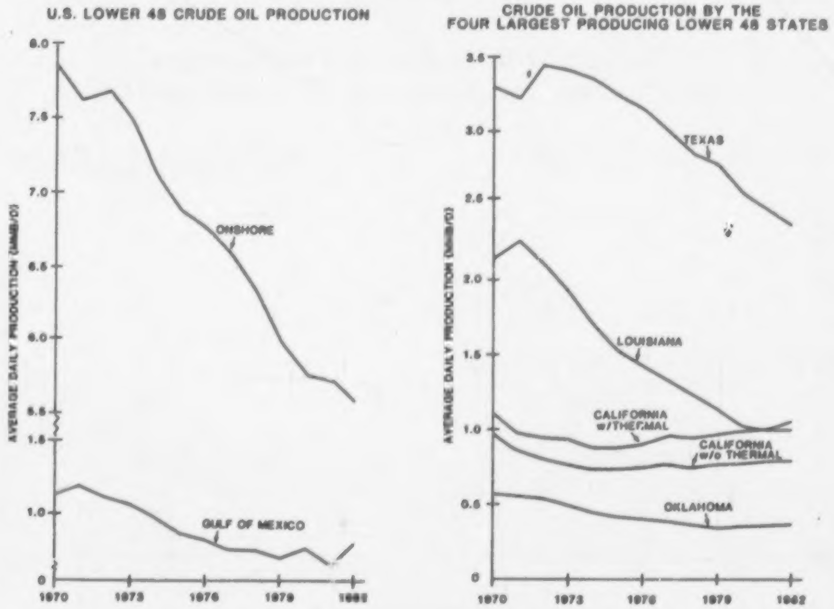
- **Both onshore and offshore production are declining, although recently higher prices have permitted longer production from marginal wells.**

- **This decline has affected nearly all 31 of the Lower-48 oil-producing states:**
  - **23 of these states had less production in 1982 than in 1970.**
  - **The eight states with increased production account for only 20% of Lower-48 production, with California alone accounting for 17%.**

- **Of the major Lower-48 producing states, all are in serious decline except California:**
  - **Increased use of thermal enhanced oil recovery processes has permitted California production to increase while that of all other major Lower-48 states has fallen.**
  - **Oklahoma production has been relatively flat due to a vast increase in the number of marginal, "stripper" wells.**

- **State governments are quite concerned about the loss of economic activity and state revenues resulting from these declines.**

Decline In U.S. Lower-48 States and State Oil Production



U.S. LOWER 48 CRUDE OIL PRODUCTION

CRUDE OIL PRODUCTION BY THE FOUR LARGEST PRODUCING LOWER 48 STATES

SOURCES American Petroleum Institute, 1980, Energy Information Administration, 1980, 1981, 1982, California Oil Producers' 1981; Oil and Gas Journal, April 5, 1982.

[illegible]

The U.S. is Increasingly Reliant on Marginal Wells

- "Stripper" wells (less than 10 B/D) accounted for more than 17% of 1982 Lower-48 production:
  - Average production per stripper well was 2.9 B/D — down from 3.4 B/D in 1970.

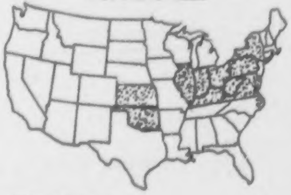
- Stripper well price decontrol (September 1976) allowed negotiated prices between controlled U.S. and world prices, permitting longer well life.

- Prolonged well life has permitted stripper wells to assume a larger role in Lower-48 production.
  - Stripper well production increased from less than 3% to more than 17% of Lower-48 production in the last decade.
  - For ten producing states, more than half of their total production is from stripper wells.

- BUT, stripper well classification indicates the rapid approach of the economic limit to production.

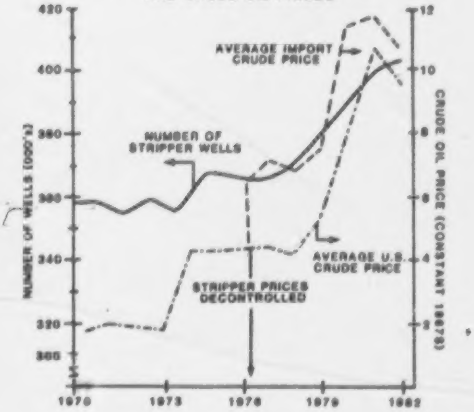
- For stripper well fields, only new technology can restore production.

STATES WITH MORE THAN 50% TOTAL PRODUCTION FROM STRIPPER WELLS

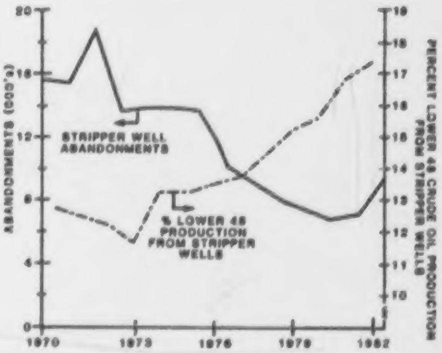


Stripper Wells Respond to Price Changes But Only New Technology Can Restore Productivity

NUMBER OF U.S. STRIPPER WELLS AND CRUDE OIL PRICES



NUMBER OF U.S. STRIPPER WELL ABANDONMENTS AND PERCENTAGE OF U.S. PRODUCTION FROM STRIPPER WELLS



SOURCES. Interstate Oil Compact Commission and National Stripper Well Association, 1983, American Petroleum Institute, 1983., Energy Information Administration, 1982.

Projected Production from Known Reserves Will Not Solve the Problem

- U.S. proved and indicated reserves at the end of 1982 totaled 29.3 billion barrels (BB):
  - Alaska accounts for about 1/4 of the total.
  - Thermal enhanced oil recovery (EOR) totals 11 % of reserves.
- 1982 production totaled 3 BB, or an average of 8 MMB/D:
  - Alaska contributed 1.7 MMB/D.
  - Thermal EOR produced an average of less than 0.4 MMB/D production.
- Projected production from currently known fields:

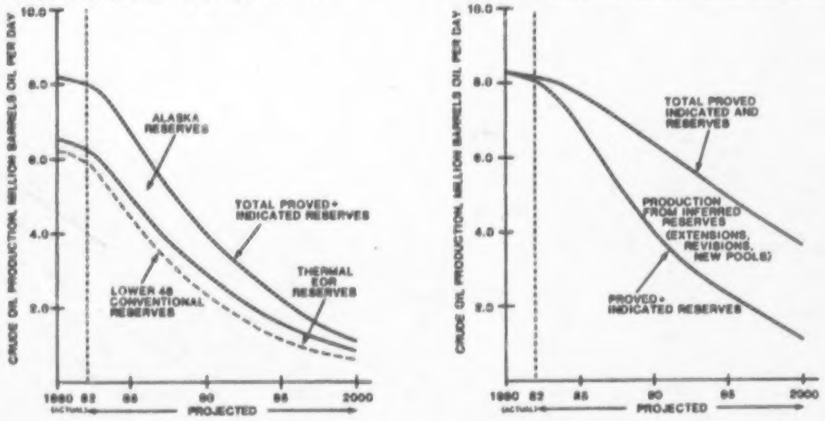
	MM B/D	
	1990	2000
Projected production from proved and indicated reserves	4.0	1.1
Projected incremental production from proved, indicated, and inferred (including extensions and revisions) reserves	2.5	2.6
Projected total production from known reserves	6.5	3.7

- Only three sources can meet the U.S. demand for oil through the rest of this century:
  - New domestic discoveries;
  - Increased production of residual oil from known domestic reservoirs; or
  - Increased imports.

Conventional Production From Known Fields Is Expected to Decline Rapidly

PROJECTED DOMESTIC CRUDE OIL PRODUCTION FROM PROVED AND INDICATED RESERVES

PROJECTED DOMESTIC CRUDE OIL PRODUCTION FROM PROVED, INDICATED AND INFERRED RESERVES



SOURCES: Actual: Energy Information Administration, 1980, 1981, 1982.
Projected: Lewin and Associates, 1984.

New Domestic Exploration Will Not Solve the Problem

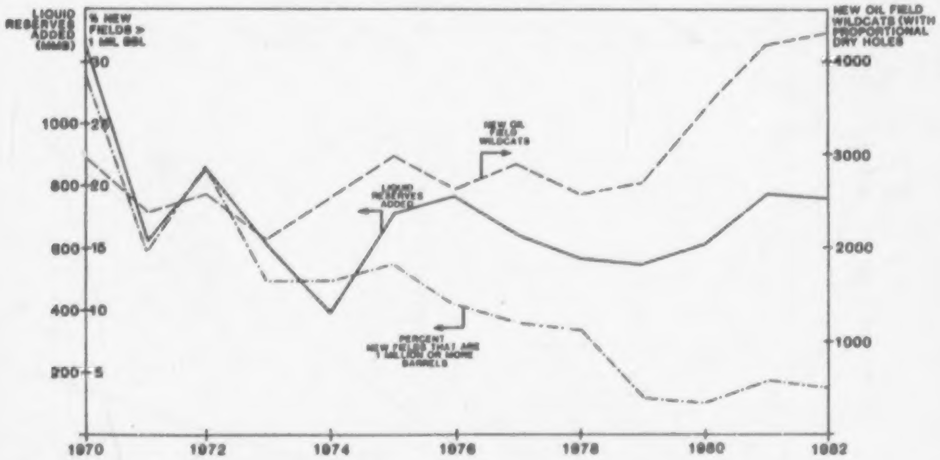
- The number of new oil field wildcat wells in the last decade has doubled, responding to significantly higher oil prices.

- However, annual reserve additions have been relatively constant, averaging 650 MMB per year (by the AAPG definition, which includes extensions and revisions added later as inferred reserves):
  - This represents only about 22% of domestic production being replaced by new discoveries.

- The doubling of exploration, however, has found smaller and smaller fields.
  - In 1972, 22% of the new fields discovered had more than one MMB of reserves.
  - By 1979, the proportion of new fields larger than one MMB of reserves — less than 1/8 of one day's production — had dropped to 3% of all discoveries and has stayed well below 4% since.

- Thus, even keeping reserve additions relatively constant at the level of 1 barrel added for every 5 produced has required drilling vastly more wells that find much smaller fields.

Reserve Additions Have Held Relatively Constant Because Vastly Increased Exploration Has Found Smaller and Smaller Fields



SOURCES: American Association of Petroleum Geologists, annual issues, 1970-82.

Future U.S. Reserves Will Cost More, But Increased Production of Known Residual Oil Will Be Among the Least-Cost Options

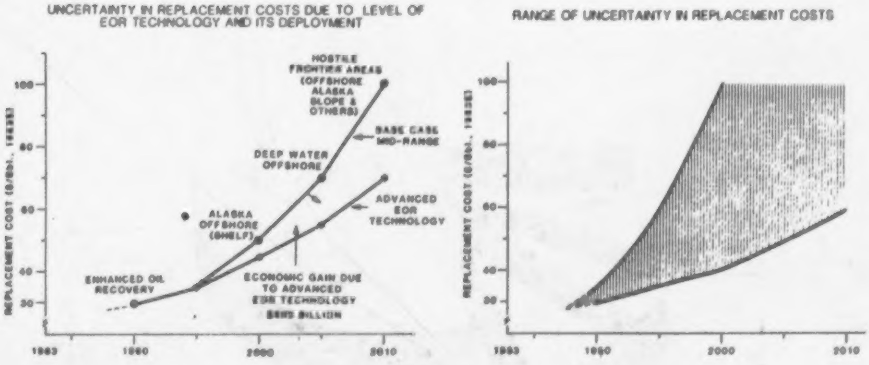
- As conventional reserves become more scarce and more economically marginal, new technologies and frontier regions remain the only domestic options for replacing reserves — all of which entail higher costs.

- The cost of replacing crude oil reserves at the 1982 production rate could rise to $50/B by the year 2000.

- Producing a higher proportion of oil from known reservoirs through enhanced oil recovery is potentially the least-cost major incremental source of replacement reserves.
  - In addition, advances in EOR technology could reduce these costs and, at the same time, increase available resources.

- The range of uncertainty in future replacement costs is broad.
  - Discouraging results of the $140 million Mukluk well in Alaska and of exploratory wells in the Atlantic offshore could argue that replacement costs could be even higher than projected.

Crude Oil Resources Replacement Costs



UNCERTAINTY IN REPLACEMENT COSTS DUE TO LEVEL OF EOR TECHNOLOGY AND ITS DEPLOYMENT

RANGE OF UNCERTAINTY IN REPLACEMENT COSTS

SOURCE Lewin and Associates, 1984

Yet, Most of the Domestic Known Crude Oil Resource -- Residual Oil -- Will Be Abandoned In Known Reservoirs

- Estimated total U.S. original oil-in-place in discovered reservoirs is 480 billion (BB).
  - 130 BB have been produced and 29 BB are classified as proved or indicated reserves.
  - The difference— 321 BB — is considered residual oil

- Thus, nearly two-thirds of known U.S. oil cannot be produced by conventional recovery technology.

- Enhanced oil recovery (EOR) encompasses a number of processes designed to produce residual oil that cannot be produced by conventional primary and secondary processes.
  - 18 to 52 BB of residual oil could be produced through processes that can be defined today for specifications.

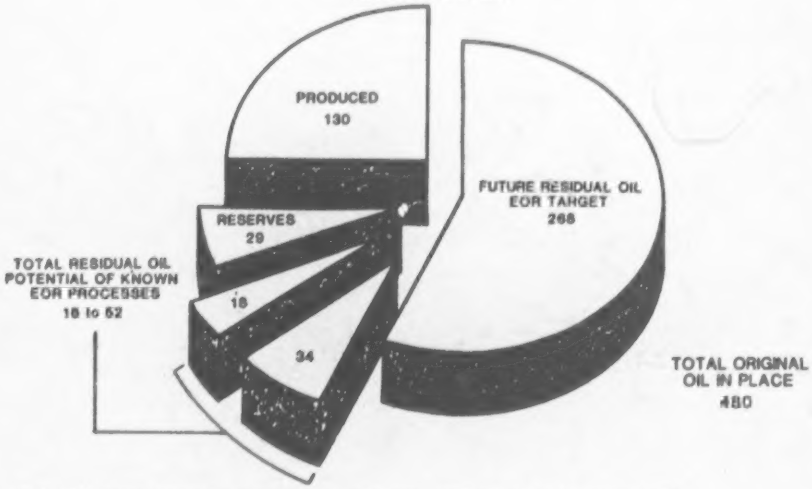
- Even then, more than one half of the known U.S. oil will remain unrecovered — the target for EOR processes that have not yet even been conceived.

- Every one percent of residual oil made producible adds one years' domestic production at current rates.

- Assured recovery of even a small portion of U.S. residual oil could fundamentally affect the prospects for the domestic oil industry and national policies regarding energy, security, and the economy.

Domestic Resource Available for EOR

(Billions of Barrels)



SOURCES: Energy Information Administration, 1980, 1981, 1982; Lewin and Associates, 1978; National Petroleum Council, 1976; Office of Technology Assessment, 1978.

Abandoned Residual Oil is Trapped in the Reservoir -- Immobile or Inaccessible to Conventional Production Technology

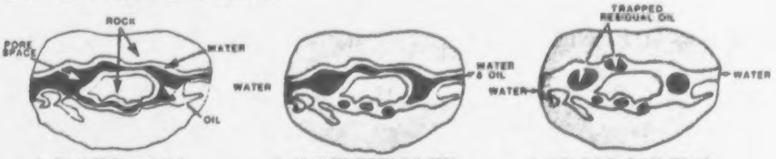
- Oil that remains in the reservoir after conventional primary and secondary recovery — residual oil — is trapped by interfacial tension, lies in zones of the reservoirs that cannot be swept by injected fluids, or is too viscous to be produced.
  - This oil resides in a different physical state and/or location than the oil produced by conventional processes.

- Primary and secondary recovery efficiency is limited to the oil that is mobilized in the areal and vertical portions of the reservoir that are contacted — collectively averaging about 33% of the original oil.

- Neither the properties nor the location of the remaining residual resource is adequately understood -- nor are the technologies for reaching, displacing, mobilizing, or producing it.

Residual Oil Is Usually Trapped or By-Passed

A. EXAMPLE OF MICROSCOPIC TRAPPING

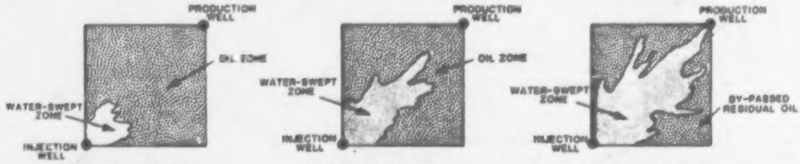

ROCK
PORE SPACE
WATER
OIL
WATER
WATER & OIL
TRAPPED RESIDUAL OIL
WATER
WATER

1. OIL IS ORIGINALLY IN A CONTINUOUS PHASE IN THE PORE SPACE

2. AS WATER ENTERS THE PORE, THROUGH NATURAL WATER DRIVE OR SECONDARY WATER FLOODING, OIL IS PUSHED OUT . . .

3. UNTIL THE OIL PHASE BREAKS DOWN INTO DISCRETE DROPLETS DUE TO INTERFACIAL TENSION. THEN, ONLY WATER WILL FLOW. THE OIL IS TRAPPED -- EVEN IN THE WATER SWEPT ZONE.

B. EXAMPLE OF AREAL BY-PASSING

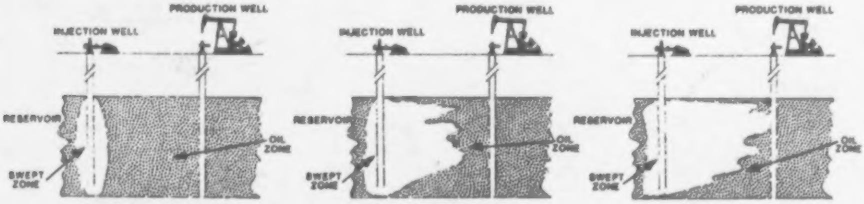

PRODUCTION WELL
OIL ZONE
WATER-SWEPT ZONE
INJECTION WELL
PRODUCTION WELL
OIL ZONE
WATER-SWEPT ZONE
INJECTION WELL
PRODUCTION WELL
WATER-SWEPT ZONE
BY-PASSED RESIDUAL OIL
INJECTION WELL

1. AS WATER IS INJECTED, IT PUSHES OIL TOWARD THE PRODUCTION WELL.

2. AS THE FLOOD CONTINUES, THE WATER-SWEPT ZONE GROWS, BUT DIFFERENCES IN MOBILITY OF OIL AND WATER AND HETEROGENEITIES IN THE RESERVOIR CAUSE "FINGERING" . . .

3. UNTIL A CONTINUOUS PATH OF WATER DEVELOPS. THEN, ONLY WATER CAN BE PRODUCED: OIL IN THE UNSWEPT ZONE CANNOT BE RECOVERED BY CONVENTIONAL MEANS.

C. EXAMPLE OF VERTICAL BY-PASSING


PRODUCTION WELL
INJECTION WELL
RESERVOIR
OIL ZONE
SWEPT ZONE
PRODUCTION WELL
INJECTION WELL
RESERVOIR
OIL ZONE
SWEPT ZONE
PRODUCTION WELL
INJECTION WELL
RESERVOIR
OIL ZONE
SWEPT ZONE

1. AS WATER OR STEAM IS INJECTED, IT DISPLACES OIL TOWARD THE PRODUCTION WELL

2. AS THE FLOOD CONTINUES, THE SWEPT ZONE GROWS BUT DIFFERENCES IN GRAVITY AND RESERVOIR HETEROGENEITIES CAUSE "FINGERING" AND "OVERRIDE"...

3. UNTIL A CONTINUOUS PATH CONNECTS THE INJECTOR AND PRODUCER, AFTER WHICH THE INJECTION FLUID FAILS TO CONTACT ADDITIONAL OIL.

SOURCE: First row of illustrations after Exxon, 1982.

Advanced Enhanced Oil Recovery has the Potential to Produce Enough of the Known Residual Resource to Offset U.S. Production Decline; But This Result is Highly Uncertain

- EOR technologies that are currently available or require only improved understanding and engineering development can add 0.4 to 0.7 MMB/D by 1990 and 1.2 to 2.2 MMB/D by 2000.

- Other EOR techniques, the so-called advanced processes, have been proposed but require substantially improved understanding, research, and development before reaching their potential — an additional 1.4 MMB/D by 1990 and 2.7 MMB/D or more by 2000.

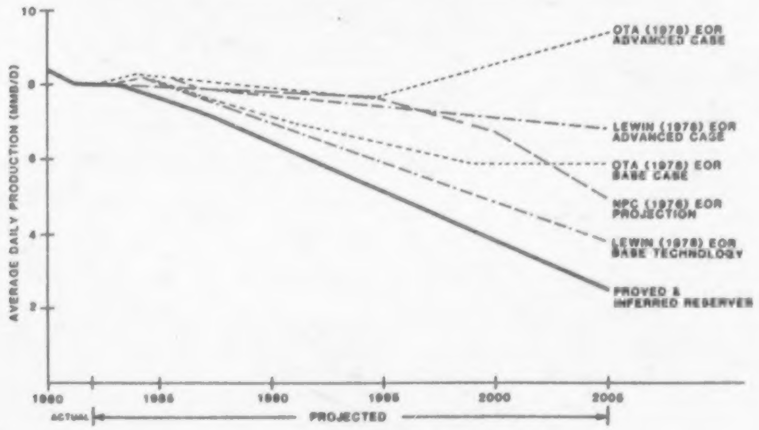
- The potential to produce a significant portion of the known residual oil resource is highly uncertain:

EOR Process	Estimated Ultimate Recovery (BB)			
	NPC, 1976 (90 % /50 % /10 %)	Lewin, 1978	OTA, 1978	Range (Interpreted)
Gas Miscible Flooding	4- 7- 9	6-13	12-21	7-21
Chemical Flooding	1- 7-13	3- 5	7-12	5-12
Thermal Recovery	4- 7- 9	8-19	6- 8	6-19
Total Potential	9-21-32	17-37	25-41	18-52

- This uncertainty reflects limited understanding of the remaining, known residual oil resources and the EOR technologies that may apply to them.

- The National Petroleum Council is currently conducting an in-depth analysis of EOR potential; its results are expected in Spring 1984.

Producing More of the U.S. Known Oil Through EOR Could Offset Domestic Production Decline



SOURCES Lewin and Associates, 1978, 1984; Office of Technology Assessment, 1978; National Petroleum Council, 1976.

However, Current EOR Production is Limited Despite Numerous Incentives

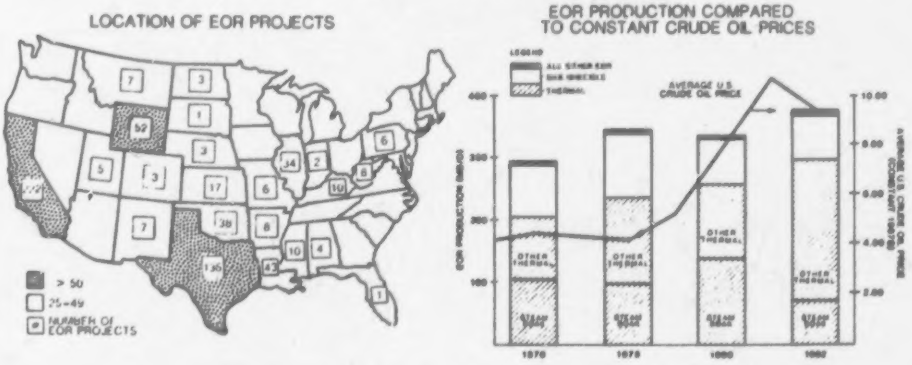
- Industry has invested billions of dollars in EOR research and field tests.

- The Federal government and the public have provided significant direct and indirect EOR incentives:
  - 26 cost-shared projects, totaling $250 million (about 40% Federal cost).
  - More than 400 projects stimulated through the Tertiary Oil Recovery Incentive Program, at a cost estimated at more than $4 billion.
  - The Windfall Profit Tax, extending the incentives still more broadly.
  - Publicly supported R&D program for more than ten years.

- While more than 600 EOR projects have been initiated, total production has remained less than 400 MB/D since 1976, less than 5% of the Nation's total.
  - Thermal recovery accounted for 79% of total EOR in 1982, up from 70% in 1976 -- nearly all from a few giant reservoirs in California.
  - Gas miscible flooding contributes essentially all the remaining — practically all from West Texas.

- In the past, EOR production has shown itself to be insensitive to either public incentives or rising oil prices outside of a few very favorable reservoirs.
  - Between 1978 and 1982, oil prices increased nearly two and one-half times, but EOR production remained essentially constant.
  - This can be changed by improved understanding of the resource and technology.

Substantial EOR Activity Has Been Stimulated By Economic Incentives, But EOR Production Has Remained Limited


LOCATION OF EOR PROJECTS

EOR PRODUCTION COMPARED TO CONSTANT CRUDE OIL PRICES

SOURCES EOR Projects DOE Bartlesville Project Office, Tertiary Oil Recovery Information System, 1984.
EOR Production Oil and Gas Journal, April 5, 1982, March 31, 1980, March 27, 1978.
April 5, 1976. Average Oil Price American Petroleum Institute, 1983.

Geologically Unique Reservoirs Account for Essentially All Current EOR Production

- Ten counties in the entire United States contain all the significant 1982 EOR production.

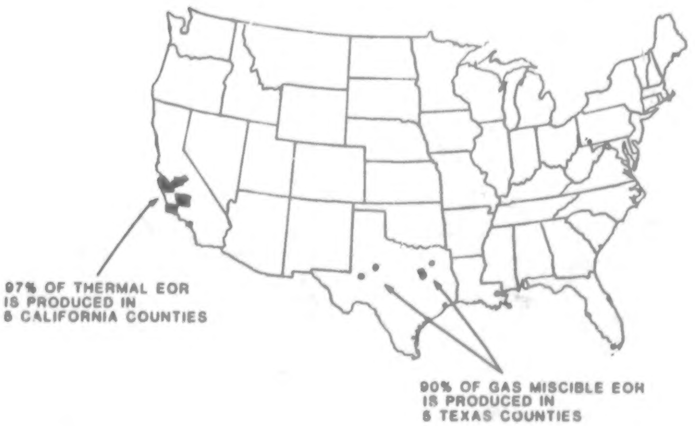
- 97% of all thermal EOR recovery is produced in five counties in California; Kern County alone accounts for 77% of U.S. thermal production, or 61% of all U.S. EOR production.
  - Ten giant reservoirs alone accounted for 59% of all 1982 thermal EOR.
  - These are ideal thermal EOR candidates, characterized by high oil saturations, very thick reservoirs, high porosity and permeability, and relative homogeneity.

- 88% of all gas EOR production came from only four reservoirs in five counties in Texas.
  - These are ideal gas EOR candidates, being thick with high oil saturation and high pressures.
  - CO_2 pipelines currently under construction will increase gas EOR from similarly favorable reservoirs, especially in West Texas.

- Thus, uniquely favorable geology accounts for essentially all current EOR production.

- In these settings, geological conditions permit economic recovery despite the lack of understanding of the resource or the processes for producing it.
  - The vast bulk of the resource, however, lies in much less favorable settings — lower oil saturation, thinner, deeper and more heterogeneous reservoirs in, for example, the Mid-Continent, Louisiana, and the Rocky Mountains (see map on page 13).

U.S. Enhanced Recovery Is Highly Concentrated In A Few Very Favorable Geologic Settings



97% OF THERMAL EOR
IS PRODUCED IN
5 CALIFORNIA COUNTIES

90% OF GAS MISCIBLE EOR
IS PRODUCED IN
5 TEXAS COUNTIES

SOURCE: Oil and Gas Journal, April 5, 1982.

Inadequate Understanding of the Residual Oil Resource and Its Response to Technology has Limited EOR and Contributes to the Major Uncertainties in Future Domestic Production

- EOR process designs, as analyzed in laboratory experiments and through detailed mathematical simulations, have promised highly effective recovery of residual oil from specific types of reservoirs.

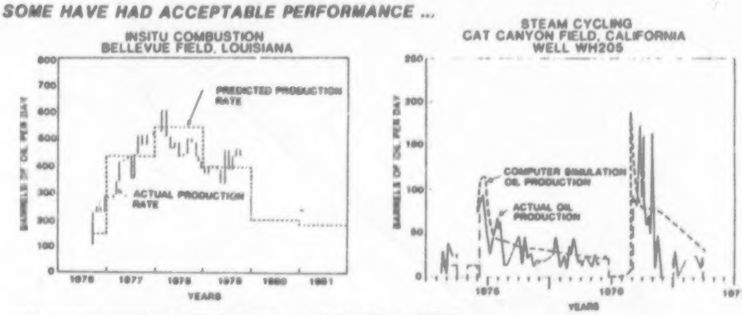
- When these designs are applied to reservoirs, they have usually failed to perform as predicted except in the most favorable reservoirs settings.

- Precisely why these processes have failed is essentially unknown, although numerous reasonable hypotheses have been developed.

- Without more adequate understanding of the residual oil resource and its recovery technologies, economic incentives cannot induce more production.
  - In fact, even the projections of potential EOR production described above contain major uncertainties concerning the resource and its recovery technologies (see p. 12).
  - But, as basic understanding and predictability are improved, recovery of residual oil will respond to economic incentives and EOR may reach its full potential.

Enhanced Recovery Projects Have Often Failed To Perform As Predicted In Actual Field Settings

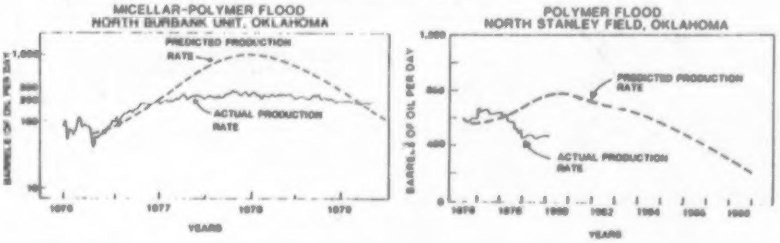
SOME HAVE HAD ACCEPTABLE PERFORMANCE ...



INSITU COMBUSTION
BELLEVUE FIELD, LOUISIANA

STEAM CYCLING
CAT CANYON FIELD, CALIFORNIA
WELL WH205

BUT MANY HAVE FAILED TO PERFORM AS PREDICTED



MICELLAR-POLYMER FLOOD
NORTH BURBANK UNIT, OKLAHOMA

POLYMER FLOOD
NORTH STANLEY FIELD, OKLAHOMA

SOURCE: U.S. Department of Energy, Enhanced Oil Recovery, 1980

SUMMARY -- Increased Recovery of Residual Oil has Significant Potential, But Is Limited by Inadequate Understanding of the Resource and the Technologies for Producing It

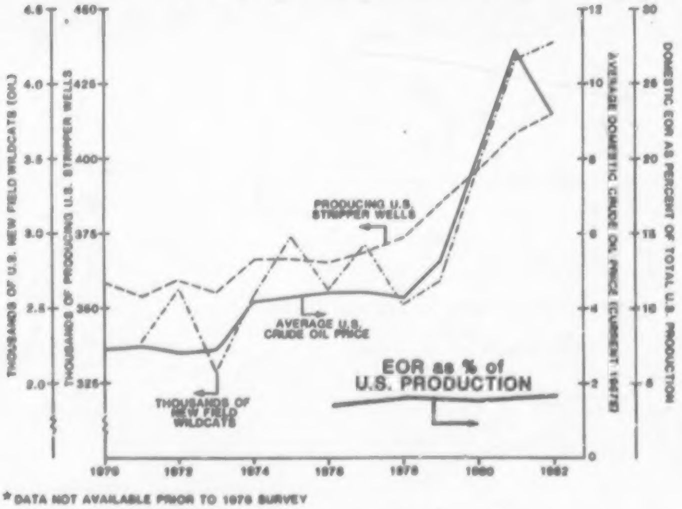
- Higher crude oil prices have stimulated a substantial exploration effort and have sustained marginal wells, but domestic production has continued to decline.

- Recovery of residual oil by EOR has not contributed significantly to production.
  - EOR production has remained at less than 400 MB/D — less than 5% of U.S. Lower-48 production — since 1976.
  - The residual oil produced by EOR to date has largely come from a very small number of near-ideal settings.

- The principle reason that more residual oil has not been produced is the inadequate basic understanding of the resource and the technologies needed to produce it.

- Given improved understanding, effective EOR processes could be developed and implemented to recover residual crude oil which could offset the decline in U.S. production.
  - At a minimum, improved understanding will permit more accurate forecasts of domestic production from known reservoirs over the critical next two decades.

Rising Prices Have Stimulated Exploration And Have Sustained Marginal Wells But Have Had Little Impact On EOR Production



*DATA NOT AVAILABLE PRIOR TO 1976 SURVEY

SOURCES: Interstate Oil Compact Commission and National Stripper Well Association, 1983. American Petroleum Institute, 1983, Oil and Gas Journal, April 5, 1982, March 31, 1980, March 27, 1978, April 5, 1976.

The Goal of Federal EOR Research Is: To Improve the Understanding of the 300 Billion Barrel Residual Oil Resource and the Technologies to Produce It

- The central premise of the Federal EOR research program is that improved understanding will permit market forces to stimulate timely production of the residual oil resource — perhaps to levels that can sustain U.S. production.

- The program is designed to produce three types of improved understanding for three distinctly different users:
  - For private and public researchers: detailed definition of the critical scientific uncertainties that limit understanding of the residual oil resource and EOR technology — to accelerate advances in understanding.
  - For private users of EOR: detailed understanding of specific types of reservoirs and applicable EOR process designs — to accelerate efficient production of residual oil, the ultimate purpose of the program.
  - For public and private policymakers: overall assessments of the residual oil resource base and valid projections of future EOR production — to improve the effectiveness of investment and policy decision making.

- The measure of the adequacy of understanding is the ability to predict accurately EOR production performance for specific process designs in particular reservoirs; when this level of understanding is reached:
  - EOR will be well enough understood to respond to economic incentives.
  - Projections of future domestic production can be acceptably accurate.
  - Federal EOR research can be concluded.

FEDERAL EOR RESEARCH GOAL

IMPROVE UNDERSTANDING 300-BILLION BARREL RESIDUAL OIL RESOURCE AND THE TECHNOLOGIES FOR PRODUCING IT

RESEARCH OBJECTIVES/PRODUCTS	USERS	EXPECTED ULTIMATE RESULT
1. Overall, current assessments of the residual oil resource and its production technologies	Federal, state and private policy-makers	Improved decisions about domestic crude production & investments
2. Refined definitions of critical resource and technical uncertainties	Private and Public EOR research community	Accelerated advances in understanding of the resource and technology
3. Detailed understanding of recovery technology in specific reservoir types	Private users of EOR processes	Accelerated, efficient production of domestic residual oil -- THE ULTIMATE PURPOSE

CRITICAL TEST OF UNDERSTANDING

ABILITY TO ACCURATELY PREDICT EOR PERFORMANCE FOR SPECIFIC PROCESS DESIGNS IN PARTICULAR RESERVOIRS

Discrepancy Analysis is the Means for Assessing the Ability to Predict EOR Performance

- The strategy of Federal EOR research is to analyze discrepancies between actual and predicted performance of EOR field tests and to use the results of these analyses to:
  - Assess residual oil production potential;
  - Define critical uncertainties in the resource and technology; and
  - Develop detailed understandings of process performance in particular reservoir types.

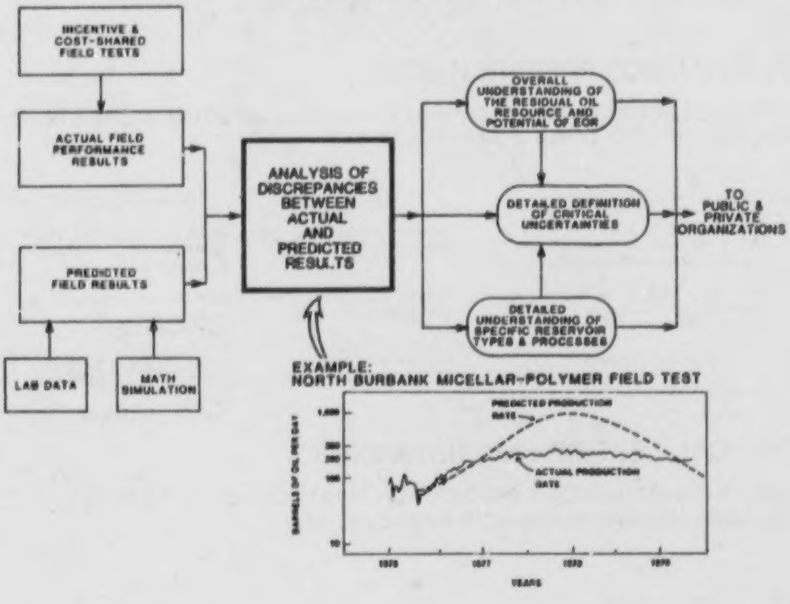
- Predicted performance is based on laboratory results and detailed mathematical simulations of the specific process designs in particular reservoirs.

- Actual results come from Federal cost-shared and incentive projects.
  - Cost-shared projects are obliged to report results in detail.
  - Three-fourths of the incentive project operators provide detailed reports voluntarily.
  - Enough of these projects are reaching maturity to support in-depth analysis of individual tests and cross-project comparisons.

- The Federal program is uniquely able to pursue this strategy because it obtains detailed data from all regions, all processes, and essentially all operators.

- The goal of the Federal program, however, is modest — it anticipates that highly focused improvements in basic understanding will permit industry to accelerate the process development and engineering refinements necessary to produce the resource.

The Heart Of The Federal EOR Research Strategy Is Discrepancy Analysis

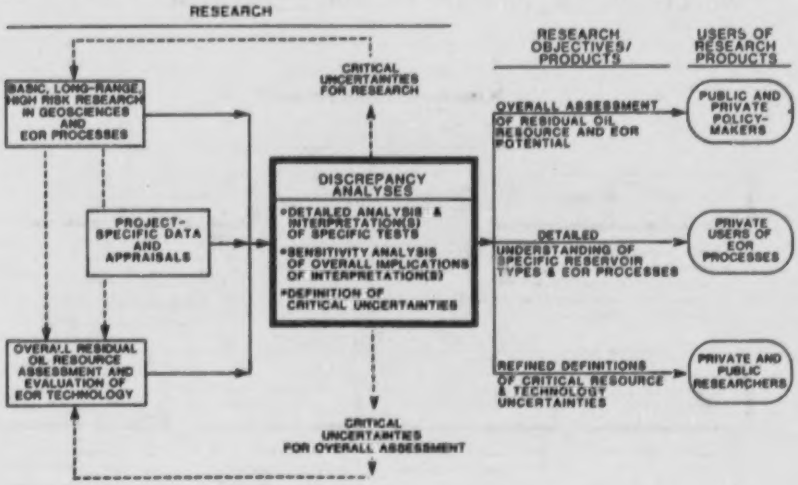

INCENTIVE & COST-SHARED FIELD TESTS
ACTUAL FIELD PERFORMANCE RESULTS
PREDICTED FIELD RESULTS
LAB DATA
MATH SIMULATION
ANALYSIS OF DISCREPANCIES BETWEEN ACTUAL AND PREDICTED RESULTS
OVERALL UNDERSTANDING OF THE RESIDUAL OIL RESOURCE AND POTENTIAL OF EOR
DETAILED DEFINITION OF CRITICAL UNCERTAINTIES
DETAILED UNDERSTANDING OF SPECIFIC RESERVOIR TYPES & PROCESSES
TO PUBLIC & PRIVATE ORGANIZATIONS
EXAMPLE:
NORTH BURBANK MICELLAR-POLYMER FIELD TEST
PREDICTED PRODUCTION RATE
ACTUAL PRODUCTION RATE
BARRELS OF OIL PER DAY
1,000
300
200
100
10
1976
1977
1978
1979
YEARS

Federal EOR Research is Driven by Critical Uncertainties as Specified through Detailed Analyses

- Collectively, the activities of the Basic Geoscience and the various EOR Process Research components reduce the critical uncertainties that are fundamental, long-range, or high-risk, and are known to have significant impacts on overall recovery of residual oil.
  - — Geoscience and Process Research activities focus on the fundamental scientific efforts that define these impacts.
  - — Geoscience and Process Research activities are directed toward those uncertainties defined as critical, i.e., having substantial impact on overall recovery.
  - — Geoscience and Process Research activities are performed by the most qualified universities, National Laboratories, DOE Energy Technology Centers, the National Institute for Petroleum and Energy Research (NIPER), and other contract research organizations.

- This research is complemented by overall assessments that capture, analyze, and report the current state-of-the-art in enhanced recovery of residual oil.
  - — Such state-of-the-art assessments are key to the vital discrepancy analyses:
    - Detailed analyses and interpretations of specific EOR field tests to determine the scientific uncertainties.
    - Sensitivity analyses to determine the implications and impacts of these uncertainties on the full resource base and its potential production rates.
    - Definition of which uncertainties are most critical.
  - — Such assessments are Federally defined and conducted due to their central role in the program.

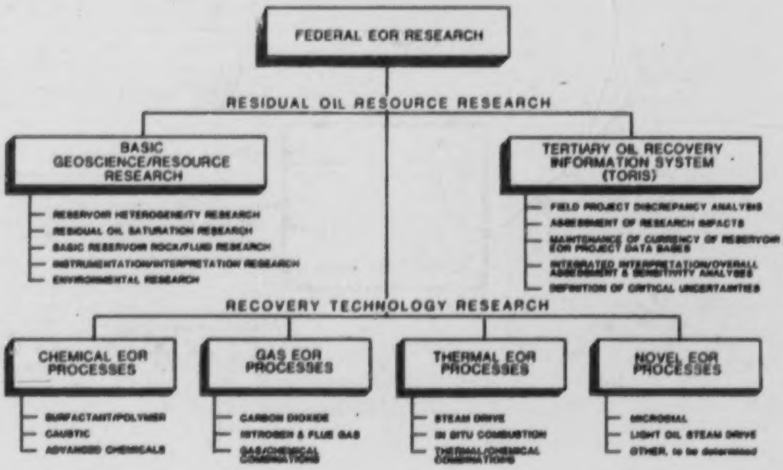
Critical Uncertainties Determine The Priorities For Federal EOR Research


RESEARCH
BASIC, LONG-RANGE, HIGH RISK RESEARCH IN GEOSCIENCES AND EOR PROCESSES
PROJECT-SPECIFIC DATA AND APPRAISALS
OVERALL RESIDUAL OIL RESOURCE ASSESSMENT AND EVALUATION OF EOR TECHNOLOGY
CRITICAL UNCERTAINTIES FOR RESEARCH
DISCREPANCY ANALYSES
•DETAILED ANALYSIS & INTERPRETATION(S) OF SPECIFIC TESTS
•SENSITIVITY ANALYSIS OF OVERALL IMPLICATIONS OF INTERPRETATION(S)
•DEFINITION OF CRITICAL UNCERTAINTIES
CRITICAL UNCERTAINTIES FOR OVERALL ASSESSMENT
RESEARCH OBJECTIVES/ PRODUCTS
USERS OF RESEARCH PRODUCTS
OVERALL ASSESSMENT OF RESIDUAL OIL RESOURCE AND EOR POTENTIAL
PUBLIC AND PRIVATE POLICY-MAKERS
DETAILED UNDERSTANDING OF SPECIFIC RESERVOIR TYPES & EOR PROCESSES
PRIVATE USERS OF EOR PROCESSES
REFINED DEFINITIONS OF CRITICAL RESOURCE & TECHNOLOGY UNCERTAINTIES
PRIVATE AND PUBLIC RESEARCHERS

Federal EOR Research Addresses Both the Residual Oil Resource and the Technologies for Producing It

- Two types of work address the residual oil resource as a whole:
  - Basic Geoscience/Resource Research: fundamental investigations of the major reservoir problems affecting all EOR processes — reservoir heterogeneity, residual oil saturation and location, basic rock/fluid interactions, measurement and interpretation of reservoir properties, and research on environmental impacts.
  - The Tertiary Oil Recovery Information System (TORIS): the central discrepancy analyses of individual EOR projects, interpretations of the significance of research results, projections of the overall production potential of the residual oil resource, and sensitivity analyses that define the critical scientific uncertainties.
- Each of the EOR processes is the subject of a major component of the program:
  - Chemical EOR processes — decreasing interfacial tension and improving sweep efficiency.
  - Gas EOR processes — mixing with, stripping, and swelling residual oil while enhancing conformance of the flood in the reservoir.
  - Thermal processes — decreasing the viscosity of heavy oils while reducing the tendency of steam to override residual oil.
  - Novel EOR processes — assessing the fundamental feasibility of emerging, experimental approaches.
- Collectively, the Program addresses the highest priority critical uncertainties of the full residual oil resource and all principal recovery technologies.

Work Breakdown Structure Of Federal EOR Research Program


FEDERAL EOR RESEARCH
RESIDUAL OIL RESOURCE RESEARCH
BASIC GEOSCIENCE/RESOURCE RESEARCH
RESERVOIR HETEROGENEITY RESEARCH
RESIDUAL OIL SATURATION RESEARCH
BASIC RESERVOIR ROCK/FLUID RESEARCH
INSTRUMENTATION/INTERPRETATION RESEARCH
ENVIRONMENTAL RESEARCH
TERTIARY OIL RECOVERY INFORMATION SYSTEM (TORIS)
FIELD PROJECT DISCREPANCY ANALYSIS
ASSESSMENT OF RESEARCH IMPACTS
MAINTENANCE OF CURRENCY OF RESERVOIR & EOR PROJECT DATA BASES
INTEGRATED INTERPRETATION/OVERALL ASSESSMENT & SENSITIVITY ANALYSES
DEFINITION OF CRITICAL UNCERTAINTIES
RECOVERY TECHNOLOGY RESEARCH
CHEMICAL EOR PROCESSES
SURFACTANT/POLYMER
CAUSTIC
ADVANCED CHEMICALS
GAS EOR PROCESSES
CARBON DIOXIDE
NITROGEN & FLUE GAS
GAS/CHEMICAL COMBINATIONS
THERMAL EOR PROCESSES
STEAM DRIVE
IN SITU COMBUSTION
THERMAL/CHEMICAL COMBINATIONS
NOVEL EOR PROCESSES
MICROBIAL
LIGHT OIL STEAM DRIVE
OTHER, to be determined

Federal EOR Research Tasks are Highly Integrated, Driven by the Critical Uncertainties Derived from Discrepancy Analysis

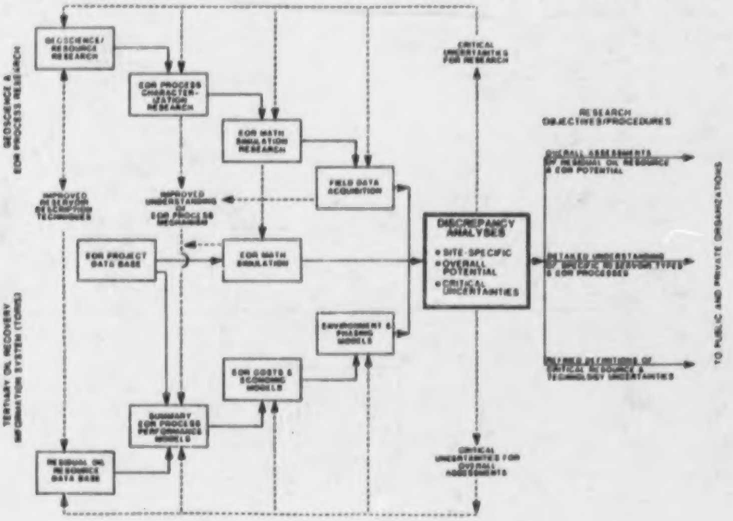
- Basic Geoscience and EOR Process Research activities are improved by being focused on the critical uncertainties as determined through discrepancy analysis.
  - — The site-specific discrepancy analyses define the scientific and technological uncertainties in precise terms.
  - — The overall assessments establish which uncertainties have highest priority, i.e., are critical for Recovery Technology Research.
  - — The basic research improves specific understanding of the resource and its necessary technologies.

- TORIS is improved by new data and new understandings derived from the Geoscience and EOR Process Research and other sources.
  - — The Residual Oil Resource Data Base is augmented by improvements in the technology for defining reservoir characteristics and locating the residual oil.
  - — The Summary EOR Process Performance Models capture current understanding by incorporating new findings from EOR Process Characterization, EOR Mathematical Simulation Research, and the EOR Project Data Base.

- Thus, critical uncertainties, defined by discrepancy analyses, determine the research priorities for Basic Geoscience and EOR Process Research activities and for TORIS.

- Through this integration, all components of the Program can meet its overall objectives; none can be effective without the others; further active information transfer disseminates the research products of all the Program's components to the relevant public and private organizations.

Logic Of Federal EOR Research Tasks Focuses On The Key Objectives


GEOSCIENCE & EOR PROCESS RESEARCH
GEOSCIENCE/RESOURCE RESEARCH
EOR PROCESS CHARACTERIZATION RESEARCH
EOR MATH SIMULATION RESEARCH
FIELD DATA ACQUISITION
CRITICAL UNCERTAINTIES FOR RESEARCH
IMPROVED RESERVOIR DESCRIPTION TECHNIQUES
IMPROVED UNDERSTANDING OF EOR PROCESS MECHANISMS
EOR PROJECT DATA BASE
EOR MATH SIMULATION
DISCREPANCY ANALYSES
• SITE-SPECIFIC
• OVERALL POTENTIAL
• CRITICAL UNCERTAINTIES
ENVIRONMENT & PHASING MODELS
EOR COSTS & ECONOMIC MODELS
SUMMARY EOR PROCESS PERFORMANCE MODELS
RESIDUAL OIL RESOURCE DATA BASE
TERTIARY OIL RECOVERY INFORMATION SYSTEM (TORIS)
CRITICAL UNCERTAINTIES FOR OVERALL ASSESSMENTS
RESEARCH OBJECTIVES/PROCEDURES
OVERALL ASSESSMENTS OF RESIDUAL OIL RESOURCE & EOR POTENTIAL
DETAILED UNDERSTANDING OF SPECIFIC RESERVOIR TYPES & EOR PROCESSES
REFINED DEFINITIONS OF CRITICAL RESOURCE & TECHNOLOGY UNCERTAINTIES
TO PUBLIC AND PRIVATE ORGANIZATIONS

TORIS: Maintaining Overall Understanding of the Residual Crude Oil Resource and Defining Research Priorities

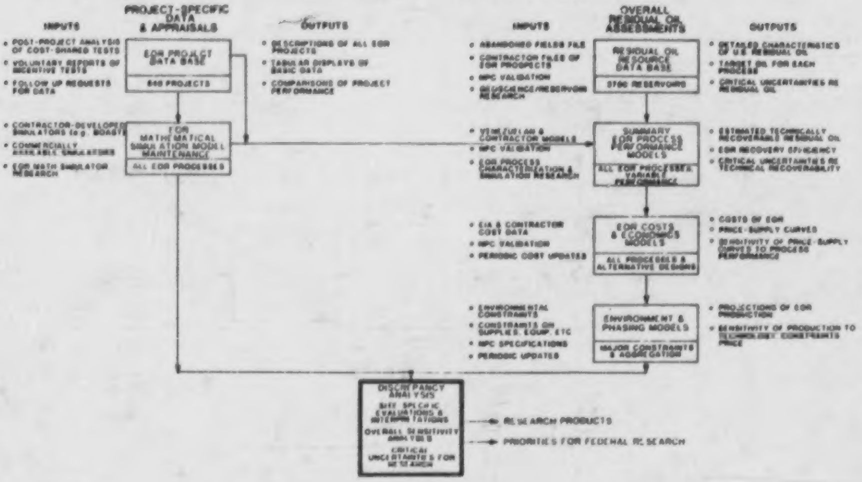
- TORIS captures and maintains the current understanding of the residual oil resource, its production technologies, and the critically important research requirements.

- The Federal government is uniquely able to maintain the currency of TORIS.
  - Data for discrepancy analyses of cost-shared and incentive projects continuously feed into TORIS.
  - TORIS data covers all parts of the domestic residual oil resource, all processes, and all operators; this is something no individual company could do.

- The National Petroleum Council (NPC) has twice contributed to TORIS.
  - In 1976, the NPC performed a major study of EOR and the residual oil resource.
  - The NPC is currently reassessing EOR at a cost of more than 60 person-years of expert analysis contributed by industry.
  - The current NPC effort has directly augmented and validated the TORIS capability.
  - Industry anticipates that DOE will maintain the currency of this investment in TORIS.

- The total private and public commitment to developing TORIS approaches $30 million since 1975.
  - ERDA Research.
  - DOE Research.
  - Industry through NPC studies.

TORIS Synthesizes The Current Understanding Of Residual Oil and Applicable Technology


INPUTS
PROJECT-SPECIFIC DATA & APPRAISALS
OUTPUTS
• POST-PROJECT ANALYSIS OF COST-SHARED TESTS
• VOLUNTARY REPORTS OF INCENTIVE TESTS
• FOLLOW UP REQUESTS FOR DATA
EOR PROJECT DATA BASE
640 PROJECTS
• DESCRIPTIONS OF ALL EOR PROJECTS
• TABULAR DISPLAYS OF BASIC DATA
• COMPARISONS OF PROJECT PERFORMANCE
• CONTRACTOR-DEVELOPED SIMULATORS (e.g. BOAST)
• COMMERCIALLY AVAILABLE SIMULATORS
• EOR MATH SIMULATOR RESEARCH
EOR MATHEMATICAL SIMULATION MODEL MAINTENANCE
ALL EOR PROCESSES
INPUTS
OVERALL RESIDUAL OIL ASSESSMENTS
OUTPUTS
• ABANDONED FIELDS FILE
• CONTRACTOR FILES OF EOR PROSPECTS
• NPC VALIDATION
• GEOSCIENCE/RESERVOIR RESEARCH
RESIDUAL OIL RESOURCE DATA BASE
3700 RESERVOIRS
• DETAILED CHARACTERISTICS OF U.S. RESIDUAL OIL
• TARGET OIL FOR EACH PROCESS
• CRITICAL UNCERTAINTIES RE RESIDUAL OIL
• VENEZUELAN & CONTRACTOR MODELS
• NPC VALIDATION
• EOR PROCESS CHARACTERIZATION & SIMULATION RESEARCH
SUMMARY EOR PROCESS PERFORMANCE MODELS
ALL EOR PROCESSES, VARIABLE PERFORMANCE
• ESTIMATED TECHNICALLY RECOVERABLE RESIDUAL OIL
• EOR RECOVERY EFFICIENCY
• CRITICAL UNCERTAINTIES RE TECHNICAL RECOVERABILITY
• EIA & CONTRACTOR COST DATA
• NPC VALIDATION
• PERIODIC COST UPDATES
EOR COSTS & ECONOMICS MODELS
ALL PROCESSES & ALTERNATIVE DESIGNS
• COSTS OF EOR
• PRICE-SUPPLY CURVES
• SENSITIVITY OF PRICE-SUPPLY CURVES TO PROCESS PERFORMANCE
• ENVIRONMENTAL CONSTRAINTS
• CONSTRAINTS ON SUPPLIES, EQUIP., ETC
• NPC SPECIFICATIONS
• PERIODIC UPDATES
ENVIRONMENT & PHASING MODELS
MAJOR CONSTRAINTS & AGGREGATION
• PROJECTIONS OF EOR PRODUCTION
• SENSITIVITY OF PRODUCTION TO TECHNOLOGY CONSTRAINTS PRICE
DISCREPANCY ANALYSIS
SITE SPECIFIC EVALUATIONS & INTERPRETATIONS
OVERALL SENSITIVITY ANALYSES
CRITICAL UNCERTAINTIES FOR RESEARCH
RESEARCH PRODUCTS
PRIORITIES FOR FEDERAL RESEARCH
]

Federal EOR Research Provides Vital Information to a Number of Agencies and Organizations and Defines the Critical Uncertainties that Guide the Research Program

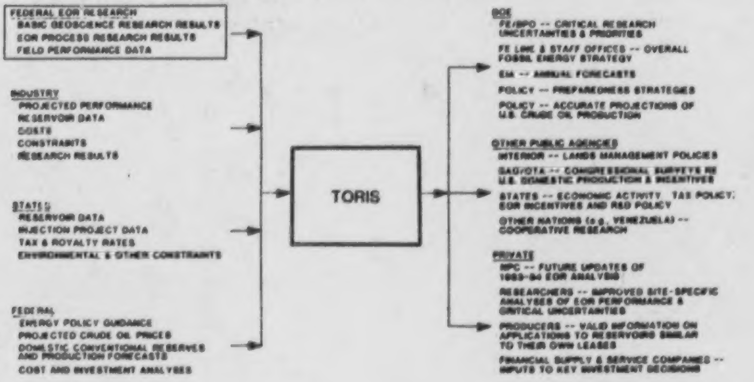
- **TORIS was originally developed to serve as a logical component of the Federal EOR research program.**
  - **It maintains a current understanding of the critical uncertainties regarding the residual oil resource and its recovery technologies based on public and private research and field results.**
  - **Its value to other organizations is increasing, especially as it sythesizes the overall EOR potential.**
  - **Such an integration and assessment structure is necessary to define and rank the priorities for the Federal EOR research program.**

- **TORIS provided the initial reservoir data and summary process models for the 1983-84 NPC study of EOR.**
  - **These were critiqued, expanded, validated, and adopted by the NPC.**
  - **The validated data and models have been returned and incorporated into TORIS.**
  - **In exchange, the NPC expects the Government to maintain and update TORIS.**

- **Requests for TORIS analyses have been received from numerous Federal, state, and private organizations.**
  - **EIA has requested assistance in forecasting production from the residual oil resource.**
  - **The Department of the Interior and the General Accounting Office have expressed interest in special analyses of EOR potential, especially on public lands.**
  - **The Interstate Oil Compact Commission, an organization of the producing states, has requested assistance in analyses of economic and tax impacts of EOR on the states.**
  - **Private firms use the results of TORIS analyses in their own R&D plans and long-range market forecasts.**

- **Because Federal EOR Research systematically captures the current understanding of both the resource and the technology, it uniquely provides valid information to its users, which no other approach could even approximate.**

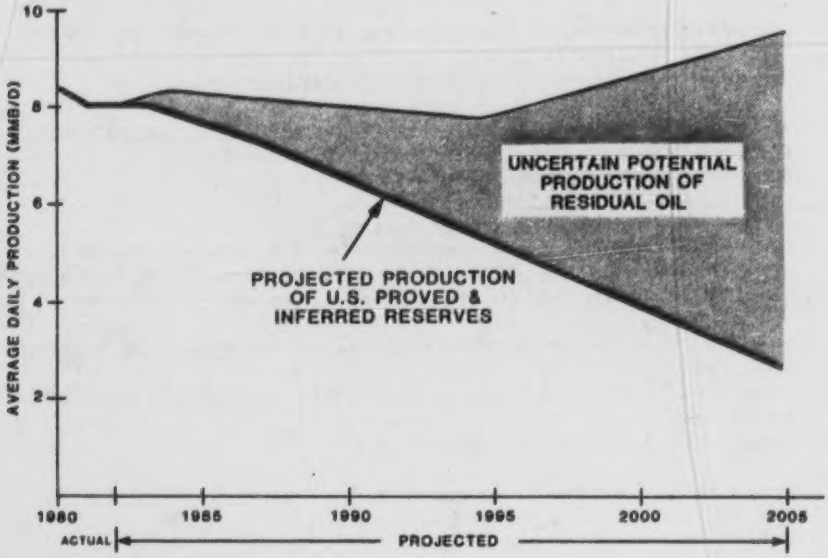
Through TORIS, Federal EOR Research Converts Data From Many Sources To Information For Many Users


FEDERAL EOR RESEARCH
BASIC GEOSCIENCE RESEARCH RESULTS
EOR PROCESS RESEARCH RESULTS
FIELD PERFORMANCE DATA
INDUSTRY
PROJECTED PERFORMANCE
RESERVOIR DATA
COSTS
CONSTRAINTS
RESEARCH RESULTS
STATES
RESERVOIR DATA
INJECTION PROJECT DATA
TAX & ROYALTY RATES
ENVIRONMENTAL & OTHER CONSTRAINTS
FEDERAL
ENERGY POLICY GUIDANCE
PROJECTED CRUDE OIL PRICES
DOMESTIC CONVENTIONAL RESERVES AND PRODUCTION FORECASTS
COST AND INVESTMENT ANALYSES
TORIS
DOE
FE/BPO -- CRITICAL RESEARCH UNCERTAINTIES & PRIORITIES
FE LINE & STAFF OFFICES -- OVERALL FOSSIL ENERGY STRATEGY
EIA -- ANNUAL FORECASTS
POLICY -- PREPAREDNESS STRATEGIES
POLICY -- ACCURATE PROJECTIONS OF U.S. CRUDE OIL PRODUCTION
OTHER PUBLIC AGENCIES
INTERIOR -- LANDS MANAGEMENT POLICIES
GAO/OTA -- CONGRESSIONAL SURVEYS RE U.S. DOMESTIC PRODUCTION & INCENTIVES
STATES -- ECONOMIC ACTIVITY, TAX POLICY, EOR INCENTIVES AND R&D POLICY
OTHER NATIONS (e.g., VENEZUELA) -- COOPERATIVE RESEARCH
PRIVATE
NPC -- FUTURE UPDATES OF 1983-84 EOR ANALYSIS
RESEARCHERS -- IMPROVED SITE-SPECIFIC ANALYSES OF EOR PERFORMANCE & CRITICAL UNCERTAINTIES
PRODUCERS -- VALID INFORMATION ON APPLICATIONS TO RESERVOIRS SIMILAR TO THEIR OWN LEASES
FINANCIAL SUPPLY & SERVICE COMPANIES -- INPUTS TO KEY INVESTMENT DECISIONS

Conclusions

- **Domestic oil production will decline seriously despite increased crude oil prices.**
- **Two-thirds of all known U.S. oil will remain in the reservoir as the fields are abandoned.**
  - **This residual oil amounts to 300 billion barrels.**
  - **It is trapped or unreachable by conventional technology.**
- **Of all domestic production options, enhanced oil recovery (EOR) — processes to produce the residual oil — is the least-cost means of offsetting the production decline.**
- **EOR has shown very limited responses to numerous incentives.**
  - **Current EOR — less than 5% of U.S. production — comes from a very small number of ideal reservoirs in California and Texas.**
  - **The potential for EOR production is highly uncertain.**
- **The limited response is largely due to inadequate understanding of the nature of the residual oil and the unpredictability of processes to recover it.**
- **The goal of the Federal EOR Research Program is to increase fundamental understanding of the 300 billion barrel resource and the technologies to produce it.**
  - **Improved understanding will improve confidence of private investors; thus,**
  - **Improved understanding will permit economic incentives to stimulate EOR production.**
  - **Improved understanding will allow more realistic expectation of future domestic production.**
- **The Federal EOR Research Program relies on analyses of discrepancies between predicted and actual EOR performance to gauge the level of understanding and to define the nature and relative importance of critical uncertainties.**
- **Understanding is increased through the interaction of the components of the program:**
  - **Basic Geoscience and EOR Process Research: increasing basic understanding of the residual oil resource and the fundamental EOR process mechanisms for recovering this oil.**
  - **Tertiary Oil Recovery Information System (TORIS): overall assessments of EOR potential, detailed site-specific discrepancy analyses and interpretations, and definition of critical uncertainties.**

SIGNIFICANT BUT UNCERTAIN POTENTIAL OF EOR



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8 American Association of Petroleum Geologists, North American Drilling Activity, annual issues, 1971-1982.

New Field Oil Wildcats found by adding the productive oil wildcats to the proportional number of dry holes.

Liquid Reserves Added is adjusted as given by AAPG's 1982 author, Robert Johnston, by 1.2 times from the initial estimate for 1978-82.

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May 6, 1983

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ENHANCED OIL RECOVERY: A KEY TO NATIONAL SECURITY

The attached documents are the result of a detailed analysis undertaken to evaluate the potential impact of Enhanced Oil Recovery (EOR) on National Security. The analysis resulted from an overall review of the EOR program that was initiated at the beginning fiscal Year 1983. The specific approach was suggested by the fact that EOR itself has not been adequately considered in all of the work on Energy Emergency Preparedness.

It appears that EOR uniquely fills the void left between when the Strategic Petroleum Reserve (SPR) would be exhausted and when a viable synfuels industry could be established. Furthermore, it is clear from the analysis that EOR can offer an inexpensive back-up to the SPR itself. The study describes a strategy which incorporates the current program (consolidating our National EOR experience, identifying significant differences between actual and predicted performance, and improving EOR theory and predictability) with a new initiative to identify and pre-engineer the major targets for EOR. It should be noted that this represents a true free market approach where the Federal role is focused on information dissemination and the private sector is responsible for most of the field work unless conditions of National emergency are reached. Because of this, the calculated benefit/cost ratio is quite positive.

The first report summarizes the analysis and presents a direct comparison of EOR with the SPR proposed optional third phase. The rapid response required under an emergency situation, however, requires pre-engineering where the most appropriate fields are identified and preliminary field work is initiated.

The second document gives a more detailed description of what pre-engineering entails and the amount of time that it can save should an emergency response be required. In addition, it summarizes a preliminary analysis of candidate fields, using existing data and screening criteria. The conclusion is that the approach is quite feasible and need only involve a small fraction of the candidate fields.

Our purpose in presenting this material is to stimulate thought and discussion during the current planning cycle. We believe that the concepts presented in these documents offer an interesting and novel approach to a pressing National problem. The analysis was initiated when oil was selling at $34 per barrel. Now that prices are falling, the conclusions appear to be even more applicable and the strategy even more urgent.

Foreword

It is the goal of the Federal Government to reduce the nation's vulnerability to energy supply disruptions and to mitigate any adverse impacts on the nation should a shortage occur. The strategy for responding to petroleum supply interruptions is to rely on the free market, supplemented as necessary and appropriate with other types of measures, such as the Strategic Petroleum Reserve.

With this goal and strategy in mind, the Bartlesville Energy Technology Center (BETC) undertook a new look at how enhanced oil recovery (EOR) could contribute to the nation's capability to respond to an energy emergency. While currently not considered part of the nation's comprehensive energy emergency response,[1] EOR represents a technology which could produce 18 to 53 billion barrels of additional oil and thus could lead to reduced national vulnerability to supply disruption. Further, with a vigorous integrated R&D program, EOR could serve to mitigate supply interruption of intermediate durations.

The market-oriented information strategy developed in this paper has important national benefits. By generating and disseminating critically important but otherwise unavailable technical information, the mature petroleum industry is expected to apply the most advanced EOR technology that economics and other conditions justify. In the absence of an energy emergency, this will allow market forces to increase domestic production, thereby reducing vulnerability to supply interruptions. In energy emergency situations of intermediate duration, the information generated would allow the industry to accelerate even marginal EOR projects and thus provide a long-lasting backup to emergency petroleum reserves. Finally, a vigorous EOR program could provide insurance for or an offset to the need for additional Strategic Petroleum Reserve capacity.

The dramatic decline in world oil prices which has occurred since BETC initiated this review in late 1982, is likely to further reduce the incentive for private industry to invest in or conduct EOR research. Therefore, a vigorous Federal Program is even more appropriate if the necessary research is to be done and information disseminated in time to assure that EOR can contribute to the nation's energy emergency response.

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[1] A Report to the Congress: Comprehensive Energy Emergency Response Procedures; the President of the United States, The Secretary, U.S. Department of Energy, December 31, 1982.

1.0 Introduction

Petroleum liquids supply approximately one-half of U.S. energy needs and nearly all transportation requirements. Petroleum is also the feedstock for chemicals, fertilizers, plastics, lubricants, synthetic fibers, pharmaceuticals, and many other products. Since the 1950s, the U.S. has joined the ranks of an increasing number of nations who find themselves with an energy shortage problem, particularly liquid transportation fuels. In the past, low-cost imports provided the solution to the problem. Unfortunately, a large portion of our imports, and that of our allies and trading partners, come from presently politically unstable or potentially unstable parts of the globe, as illustrated below for 1981.(1)

Source	MMbbl/day*
Middle East	1.226
Africa	1.334
Latin America	0.807
Other	0.993
TOTAL IMPORTS	4.360
Domestic Production Total:	8.562

* MMbbl/day - million barrels of oil per day
Mbbl/day - thousand barrels of oil per day

These supplies are susceptible to disruption, both at the points of supply and along transportation routes. Based on recent assessments, the probability of an import disruption of some type is approximately 40% in any year.(2) There have been 13 disruptions since 1951. They have lasted from one month (refinery explosion) to 44 months during the overthrow of the Iranian Government. Associated shortfalls have been as high as one-third of Persian Gulf production, averaging about one million barrels per day.

The probability of disruptions that last one year or more have been calculated as follows:(3)

World Supply Disruption	Probability	U.S. Supply Impact
3 MMbbl/day	75%	1 MMbbl/day
10 MMbbl/day	30%	3 MMbbl/day
20 MMbbl/day	5%	5 MMbbl/day (total)

2.0 Current Alternative Energy Emergency Responses

The strategy for responding to petroleum supply interruptions and other types of energy emergencies is to rely on the free market, supplemented as necessary and appropriate with other measures such as Strategic Petroleum Reserve drawdown, international cooperation, surge production and measures to facilitate market adjustments. In severe emergencies, the provisions of the Defense Production Act and other extraordinary authorities to meet defense petroleum needs would be used.(10)

A number of alternative supply responses are available to the marketplace and to the Federal Government to mitigate a supply disruption. These available supply responses among others include:

Duration of Interruption	Response	Response Time
Short-term	Private Stocks	Immediate
	Strategic Petroleum Reserve	Immediate
Intermediate	Fuel Switching In-Fill (Drilling)	Up to 2 years
	Enhanced Oil Recovery (with pre-engineering)	1 to 3 years
Long-Term	Synthetic Fuels	5 to 7 years

2.1 Short-Term Duration Interruptions

For disruptions of short duration (0-24 months), free market actions can be supplemented with drawdowns of industrial stocks and, as necessary, drawdown from the Strategic Petroleum Reserve and military stocks.

The private stocks of crude and refined products represent private sector "self-insurance" against short-term duration interruptions. As of December 24, 1982, private stocks were about 880 MMbbls or approximately 190 days of imports at the current rate of 4.6 MMbbl/day. These stocks will fluctuate depending on market forces.

Government-owned reserves represent another source of supply to mitigate the adverse affects of a supply interruption. The SPR represents a significant capability to reduce the impacts of unexpected supply disruption. The SPR capacity will be 750 million barrels (MMbbl) in 1990. Currently, the SPR holds over 300 MMbbl and is being filled in FY 1983 at a rate of 220 thousand barrels per day (Mbbl/day). In FY 1984, it is proposed to reduce the fill rate to 145 Mbbl/day which would permit a cumulative fill of 410 MMbbl by the end of FY 1984.(4)

STRATEGIC PETROLEUM RESERVE

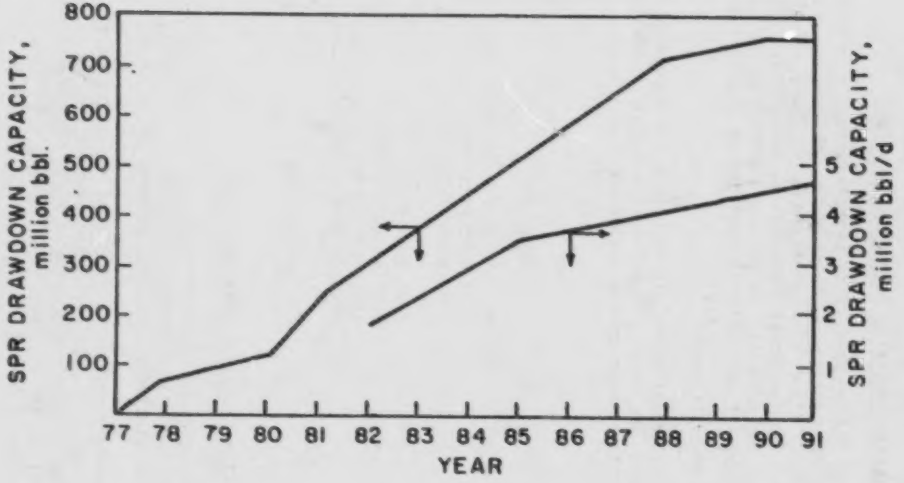


Figure 1

The current drawdown capability of the SPR is 1.7 million barrels per day (MMbbl/day). This will increase to 3.5 MMbbl/day in FY 1986 and to approximately 4.5 MMbbl/day when Phase III is completed in FY 1990.(5,6) Figure 1 provides an indication of the drawdown rates versus storage levels.

Figure 2 illustrates the SPR systems drawdown rate profile (i.e., maximum rate vs. time) as it is currently and as it will be at the end of Phase II and Phase III. The exact shape of the profile is dependent on a number of factors including cavern sequencing, transportation requirements and crude type mix requirements.

In addition to the reserves which are available, there is the potential to increase the production of oil and gas from fields on Federal, state, and private lands for which maximum efficient rates of production and temporary emergency production rates have been established.(10) It has been estimated that approximately 325 Mbbl/day additional oil production could be achieved within 4 months and could be sustained for 6-12 months without undue damage to the reservoirs.(11,12)

2.2 Intermediate Term Disruptions

The supply enhancement alternatives to respond to an interruption of up-to-ten years are currently limited.

Fuel Substitute

Fuel substitution, natural gas, and the substitution of coal for oil are often cited as measures to mitigate the impacts of supply interruptions of intermediate duration. It has been estimated that the fuel switching could result in saving oil as follows:(11,12)

Type Switching	Oil Saved Mbbl/day	Response Time (months)
Oil to Gas	50	3
	200	6
	435	12
Oil to Coal	5	6
	213	12

While the magnitude of the oil saved is not insignificant, it should be recognized that this is oil mainly used in industrial and utility boilers. These heavier oils often are produced from "heavy sour" crudes such as those from Venezuela since their yields of lighter fuels (e.g., gasoline, diesel, JP-4, etc.) are low due to the requirement for more severe and expensive processing. Further, in-place refinery equipment would have to be modified to produce the lighter fuels from these heavy crudes. Finally the conversion from oil to coal may involve high capital expenditures for environmental control, boiler conversions, and fuel preparation.

SPR DRAWDOWN CAPABILITY MODEL
DRAWDOWN RATES
SPR SYSTEM TOTAL

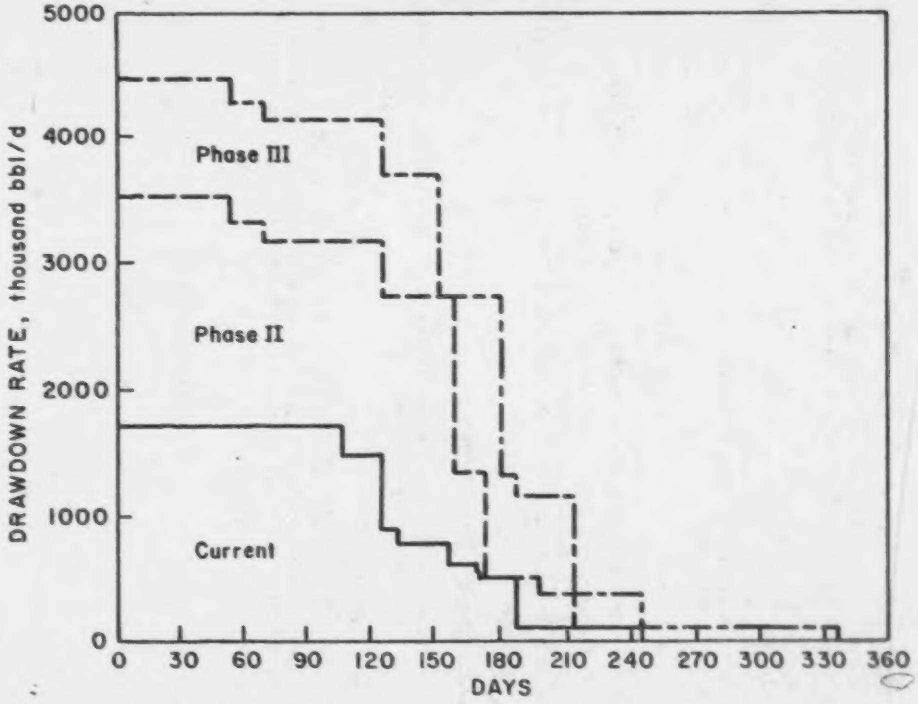


Figure 2

Converting a major portion of the transportation sector to natural gas or alcohol would take much too long to have any significant effect except in certain types of centralized fleets.

In-fill Drilling

In-fill drilling, i.e., decreasing the spacing between producing wells in a field, can increase the production rate but not the overall quantity of reserves in known fields. However, oil price decontrol and the dramatic increase in prices over the last few years has already resulted in substantial in-fill drilling, thereby reducing the opportunities for major additional production by this means. Under emergency conditions, Federal intervention encouraging in-fill drilling could provide some additional production of crude oil.

Enhanced Oil Recovery

Enhanced oil recovery (EOR) represents a significant potential contribution to providing increased oil supply to mitigate an intermediate-term disruption. Although the amount of oil that can be recovered by EOR techniques is uncertain, a reasonable estimate is from 18 to 53 billion barrels. Under expected economics and industry's planned R&D, "current" EOR technology is expected to produce 0.7 MMbbl/day by 1990 and 1.1 MMbbl/day by 2000. If advanced EOR processes could be made predictable, an additional 1.4 MMbbl/day could be expected in 1990 and 2.7 MMbbl/day in 2000. Normal time to production using EOR techniques is 3 to 5 years; however, this time could be shortened to 1 to 3 years if fields are pre-engineered.

2.3 Long-Term Interruption

Long-term interruptions could be met through increased oil production, including EOR, fuel switching, and through production of synthetic fuels from coal and oil shale.

Had a commercial coal and oil shale synthetic fuel production capability been developed as envisioned by proponents in the mid 1970s, synthetic fuels would by now be starting to reduce the need for imports. This industry, however, has not materialized due to economic and political factors. Even with a national commitment now, it is unlikely that a significant production capacity would be in place before the mid 1990s. Plant start-up lead-times are presently on the order of 7-10 years. If this commitment were made, the capital requirements would be immense. Cost estimates to offset 50 percent of our imports are on the order of $160 billion (assuming 50,000 barrels per day from 40 plants each costing $4 billion). The overall national impact would be enormous. For example, the plants would consume one-half of present coal production.

DOMESTIC RESOURCE AVAILABLE FOR EOR IS ENORMOUS

(Billions of Barrels)

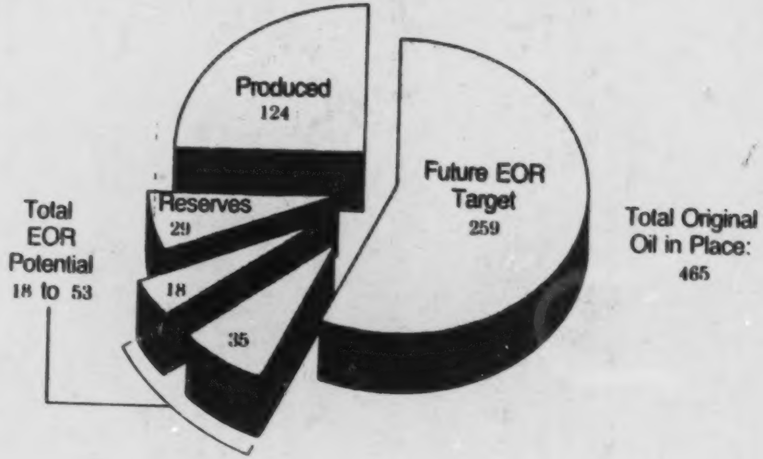


Figure 3

3.0 Enhanced Oil Recovery

3.1 Resource Base

Figure 3 displays the distribution of the total oil thus far discovered in the United States. Of the 465 billion barrels of domestic oil discovered, over 300 billion barrels will not be recovered by conventional techniques (primary and secondary recovery). The target for enhanced oil recovery is enormous and offers the most practical alternative for liquid fuels now available. Although the amount of oil that can be recovered by enhanced oil recovery (EOR) processes is uncertain, a reasonable estimate is from 18 to 53 billion barrels. Of these, 12 to 34 billion barrels are light (premium) oil (25 degrees API or higher) compared to 6 to 19 billion barrels of heavy oil.

3.2 EOR Technology

Enhanced Oil Recovery (EOR) consists of a number of techniques aimed at recovering the oil that would otherwise be abandoned after primary and secondary production have been exhausted. In general, EOR involves the injection of various substances into the reservoir to displace and mobilize the residual oil remaining after conventional recovery operations. The injected materials and specific process designs depend on the characteristics of the crude oil and of the reservoir. For descriptive purposes, the processes can generally be grouped according to whether the residual crude is "heavy," i.e., highly viscous, with high specific gravity or "light," i.e., less viscous, lower specific gravity. Figure 4 characterizes the range of efficiencies and the production potential for the EOR processes applicable to these crudes.

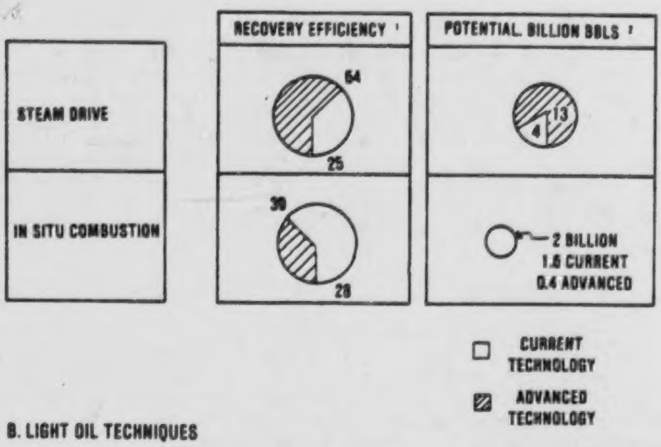
The graphic representations in Figure 4 summarize the best data now available, and the ranges present a clear view of the uncertainties surrounding EOR application. For example, steam drive in heavy oil reservoirs is expected to recover between 25 percent and 64 percent of the resource present at the start of injection. Current technologies, performing at the lower end of the efficiency range, could produce as much as 4 billion barrels. Advanced technology, with their associated improvements in sweep efficiency, are expected to recover an additional 13 billion barrels of oil.

For heavy crude oils, the primary mechanism of EOR is the application of heat. The EOR processes of steam drive/flooding and in situ combustion heat the reservoir, reducing the viscosity of the heavy oil and allowing it to be more easily driven to the producing well.

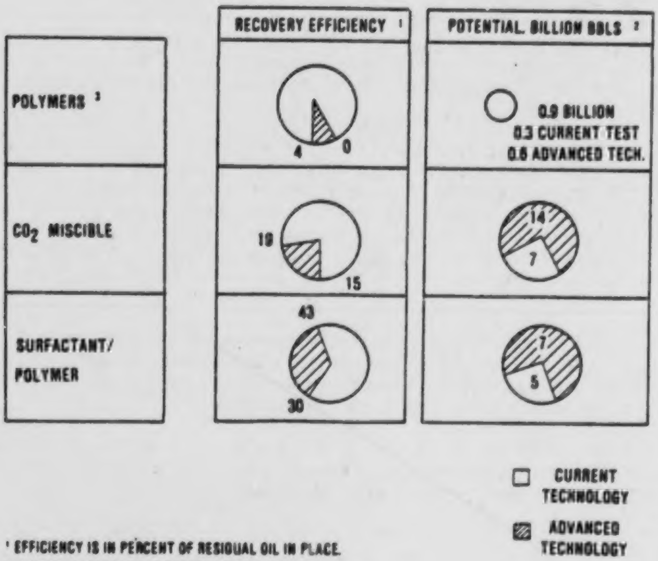
For lighter crude oils, two principal processes, chemical and gas displacement, may be applicable depending on the specific properties of the crude and the reservoir which holds the crude.

Chemical flooding EOR includes polymer flooding, surfactant-(or micellar-) polymer flooding, and alkaline flooding. In other light oil reservoirs, EOR consists of flooding by gases, most often carbon dioxide which strips lighter components of the crude oil. Other inert gases (nitrogen or flue gas) could also be injected to push or strip the oil from the reservoir rock under certain conditions.

A. HEAVY OIL TECHNIQUES



B. LIGHT OIL TECHNIQUES



[1] EFFICIENCY IS IN PERCENT OF RESIDUAL OIL IN PLACE.
[2] SOURCE: BARTLESVILLE ENERGY TECHNOLOGY CENTER.
[3] INCLUDES ALKALINE.

Figure 4

Figure 3 also points out the fact that "current" EOR technology has the potential to recovery 18 billion barrels of the 53 billion barrels, and "advanced" technologies may be able to recover the remaining 35 billion barrels. The current technologies refer to those processes and reservoir combinations that are simpler, less risky, better understood and require smaller capital investments than the more advanced methods. They, however, generally recover little of the remaining oil left in the reservoirs; i.e., their recovery effectiveness is low. On the other hand, the advanced, high-risk, EOR processes which have shown great promise in recovering large amounts of residual oil both theoretically and in the laboratory have not fared well in the field. Our understanding is not sufficient to explain this discrepancy. At present, these processes are too unpredictable to qualify as sound business investments by the oil industry.

The problem in getting the known additional oil in the reservoirs centers on the concept of "movable" vs. "immovable" oil. It is not an economic problem; i.e., simply injecting more polymer or carbon dioxide will probably not produce significant additional quantities of oil. The remaining oil exists in portions of the reservoir either in individual pores or clusters of pores; as a film lining the pore walls; or in the pores of those segments of reservoir rock which by geological conditions or well positioning were not contacted by driving fluids.

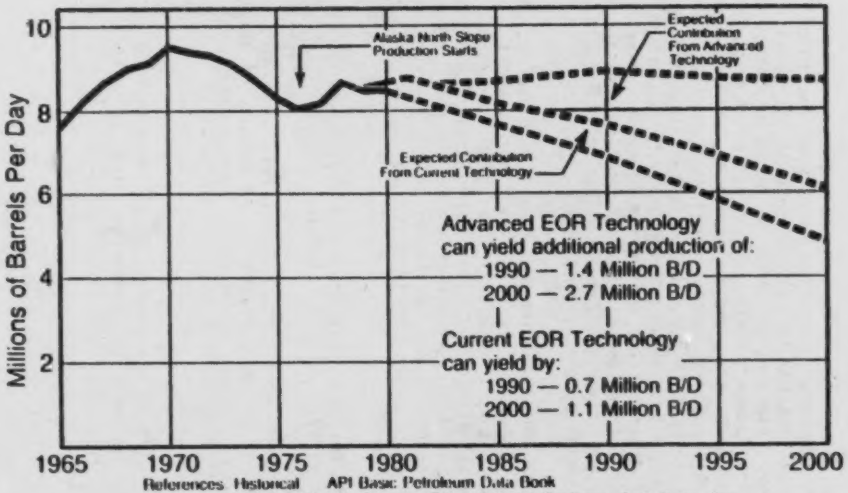
The forces that contribute to the retention of the oil are capillarity (blotter effect), gravity (buoyancy effect), and viscous forces (drag effect). These forces act simultaneously in the reservoir and the resultant effect depends on conditions at individual locations. Releasing the remaining oil so that it can be produced is the purpose of advanced enhanced oil recovery operations. Through chemical or thermal means, the objective is to increase the effectiveness of oil removal from pores of the rock (displacement efficiency) by eliminating or minimizing the oil-imprisoning capillary forces; by overcoming or utilizing the effects of gravity which cause vertical segregation of the fluids in the reservoir; by thinning the oil so that it will flow more readily; and by improving sweep efficiency, causing the injected or driving fluids to contact more of the oil-containing reservoir rock.

Technological feasibility of the processes, however, is only half of the picture; we must also learn how to characterize potential reservoirs in order to match them with the appropriate stimulation technique. Thus, the basic requirement is for a better understanding of the reservoirs, stimulation techniques, and how they interact.

It is important to note that even after the full exploitation of these EOR processes, both current and advanced, up to 259 billion barrels remain as the target for even more advanced processes. A number of novel concepts have been proposed but have not yet reached the stage of engineering studies.

The estimated potential production rates from both current and advanced EOR under non-emergency conditions are shown in Figure 5. It excludes oil that might be produced under emergencies or that might be produced by the, as yet unstudied, novel concepts.

ADVANCED EOR CAN ARREST DECLINING OIL PRODUCTION RATES



References: Historical — API Basic Petroleum Data Book
Forecast Decline Curve — Policy & Fiscal Guidance, Asst. Secy., for Policy & Evaluation, February 8, 1980
EOR Production Forecast — Lewin & Associates

Figure 5

The solid line represents historical production; the three broken lines are projections. The lowest of the three projections estimates the production from fields under conventional primary and secondary recovery technology. It reflects the generally expected decline in domestic production, even accounting for new discoveries. The two higher curves represent the incremental EOR production that is economically viable under two technological assumptions. The middle curve ("Current EOR Technology") represents EOR production, assuming that EOR technologies currently available or made practical by on-going and planned EOR research by private industry, will be exploited as economically justifiable. The Current Technology is projected to contribute 0.7 million BPD in 1990 and 1.1 million BPD in 2000. The upper curve ("Advanced EOR Technology") reflects EOR production attributable to advances in EOR performance over and above industry's current and planned levels. Such advanced processes, some still in their infancy and all requiring R&D, can contribute an additional 1.4 million BPD by 1990 and 2.7 million BPD by 2000.

3.3 Enhanced Oil Recovery - A National Security Insurance Policy

A market-oriented strategy in enhanced oil recovery (EOR) can serve as a key security measure by providing: (1) an insurance or offset to SPR, (2) incremental production to mitigate intermediate-duration shortages, and (3) a capability to reduce long-term vulnerability.

EOR could provide insurance for the SPR or possibly offset some of the future SPR storage requirements thus reducing Federal outlays without compromising national security. The SPR was started in 1977 and includes three phases. Phase I is complete and most of the funding investment for Phase II has been completed. The Phase II fill program will be complete in FY 1986. Phase III was started in FY 1983 and is scheduled for completion in FY 1990.(6,8) Phase III of SPR consists of an additional incremental storage of 30 MMbbl at the West Hackberry site and 40 MMbbl at the Bryan Mound site. The addition of this incremental storage will not increase the drawdown capability of the SPR. A new site at Big Hill, Texas, is planned for development to store 140 MMbbl and adds 935 Mbbl/day to the peak drawdown capability of the SPR.

There is a significant difference in the cost of the incremental storage versus the cost of developing the new Phase III storage capacity. The average per barrel cost for the incremental storage of West Hackberry is estimated to be $2.37/bbl to $3.31/bbl in nominal dollars or $1.67/bbl to $2.27/bbl in real 1982 dollars. The new storage at Big Hill is estimated to be $5.45/bbl to $6.54/bbl in nominal dollars or $4.04/bbl to $4.88/bbl in real 1982 dollars.(5) Total cost of Big Hill is estimated to be 763 to 915 million dollars in nominal dollars. These estimates include operation and maintenance costs through fill of the site or through FY 1988 whichever is later. It does not include the cost of oil.

The development of Phase III has begun at Bryan Mound and West Hackberry. Site acquisition activities and completion of detailed design work at Big Hill are planned for FY 1983. However, a decision on whether to proceed with construction activities at Big Hill is being reexamined. Big

Hill construction has already been delayed one year, thus delaying the completion of the 750 MMbbl SPR by one year, to 1990.[4,6]

Since the investment programs for Phase I and II are essentially complete and the Phase III incremental expansion activities at Bryan Mound and West Hackberry are well underway, it appears appropriate to consider the possibility of EOR to supplement or offset the need for the new Big Hill storage facility only.

There are three major factors affecting national security which must be considered in assessing the potential of EOR as insurance for or offset to the Big Hill addition to the SPR. These factors are: (1) total oil available to the nation; (2) production or drawdown rates; and (3) emergency response time.

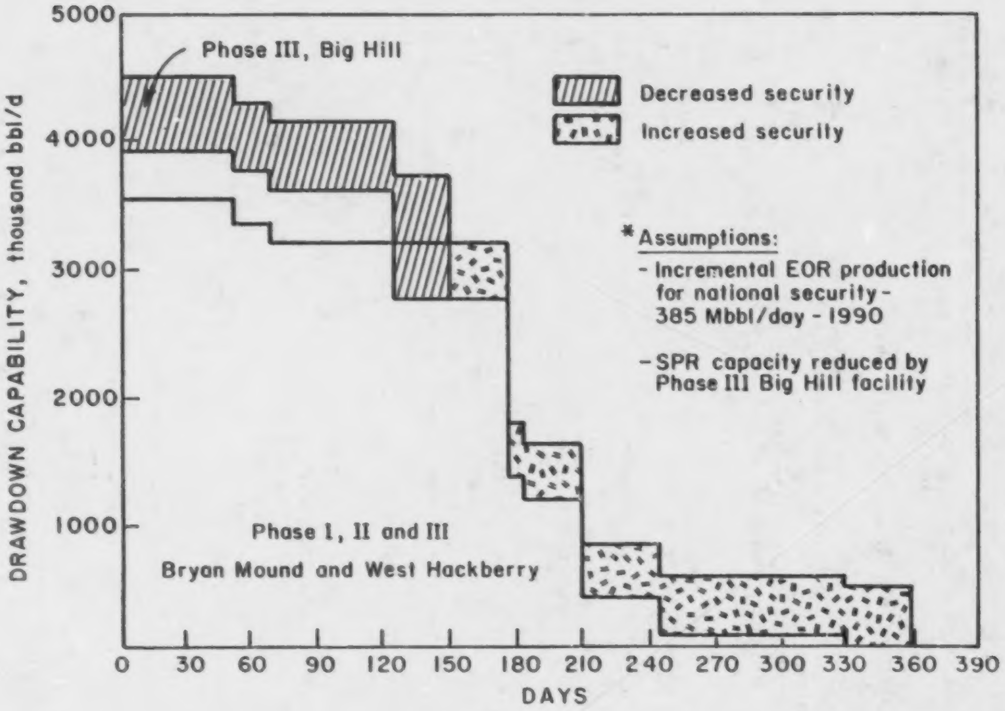
The SPR Big Hill storage facility will start to be filled in FY 1988 when 13 MMbbl will be stored. FY 1989 will see this increase to 60 MMbbl and in 1990 to its capacity of 140 MMbbl.[9] Providing the equivalent to the Big Hill SPR storage would require an average production from EOR as follows:

	Big Hill Storage MMbbl	Average EOR Equivalent Production Mbbl/day/yr
FY 1988	13	35.5
FY 1989	60	164.4
FY 1990	140	383.6

As shown in Figure 5, advanced EOR techniques could lead to the additional production of oil in the amounts needed to offset the FY 1988 to FY 1990 Big Hill storage capability. To assure the total oil available to the nation is equivalent to the 140 MMbbl contained in the Big Hill storage, an incremental production of approximately 385 Mbbl/day from advanced EOR technologies would be required by the year 1990. A separate analysis has demonstrated the gross feasibility of achieving the 1990 drawdown rate of 385 Mbbl/day, with considerable upside potential beyond that level. Depending on the level of planning, pre-engineering and technological advancement, this level of production could be achieved within as little as 1 to 1-1/2 years from the initiation of EOR injection.

Assuming that these advanced EOR techniques lead to the 385 Mbbl/day production by 1990, the nation would have, in an emergency, the same total oil available as it would with the full Phase III SPR. The penalty would be a reduction in the availability rate of the combined SPR drawdown rate and advanced EOR production. With the full SPR, the maximum drawdown rate is approximately 4.5 MMbbl/day whereas with the 385 Mbbl/day EOR production and the Phase III SPR without Big Hill, the equivalent maximum availability rate is approximately 3.9 MMbbl/day. This represents a reduction in maximum availability rate of approximately 12%. The reduction in maximum availability rate would be for 150 days, after which the combined SPR drawdown capability and the incremental advanced EOR production rate is greater than the SPR drawdown rate only. This is illustrated in Figure 6.

EOR SECURITY INSURANCE PROGRAM*



*Assumptions:
- Incremental EOR production for national security - 385 Mbbl/day - 1990
- SPR capacity reduced by Phase III Big Hill facility

Figure 6

If advanced EOR leads to the maximum plausible 1990 production of 1.4 Mbbl/day, the combined drawdown rate of SPR without Big Hill and advanced EOR incremental production would be approximately 4.9 Mbbl/day or 10% higher than the full SPR capability alone. Further, the nation would have a security benefit of an additional 370 Mbbl of oil available during a major emergency lasting one year. This benefit is shown in Figure 7.

In summary, advanced technologies offer the potential to produce the oil in both the quantities and the rates necessary to offset the Big Hill increment of SPR storage. The timely addition to domestic production from advanced EOR could allow the reduction in Federal outlays and also provide long lasting supplies of oil, thus reducing the nation's long-term vulnerability.

The remaining national security factor, emergency response time, is somewhat more difficult to assess. The SPR's response time is immediate. If EOR production is not in place, then a delay in responding to an emergency will occur. However, this response time can be reduced by identification and pre-engineering of the most promising fields and reservoirs for emergency EOR application. As promising reservoirs are identified, they can be pre-engineered to implement state-of-the-art EOR processes for rapid response to emergencies and be rank-ordered into a graduated, orderly response. As the technology advances, the pre-engineering can be updated and the overall strategy adjusted to exploit the higher yield, advanced EOR processes. As the engineering and technology improvements suggest economically producible EOR projects, operators will be able to accelerate the application of EOR under normal market operation even without an emergency condition. Under emergency conditions, Federal intervention may be necessary to encourage the application of advanced EOR technologies to produce additional crude oil.

EOR can provide a long-lasting backstop after exhaustion of the SPR. Having reservoir/process information available, the industry could reduce the implementation from an estimated three to five years to one to three years in emergency situations and thus contribute to an energy-emergency response of intermediate duration. An example of the impact of EOR during an intermediate-duration supply interruption of 2 MMbbl/day is shown in Figure 8. The assumptions associated with this example are:

- Disruption - 2 MMbbl/day
- SPR stock - 610 MMbbl[2]
- Industrial stock - 600 MMbbl
- Fuel Switching
  - Oil to Gas - 435 Mbbl/day after 24 months
  - Oil to Coal - 210 Mbbl/day after 24 months

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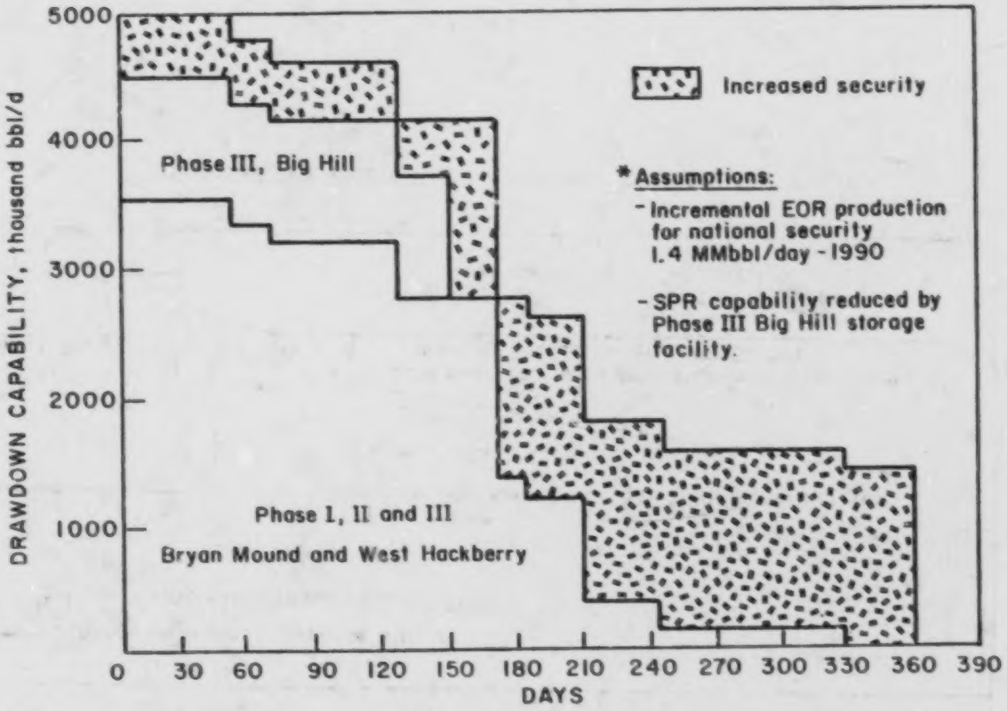
[2] Phase I, II plus Bryan Mound and West Hackberry Phase III addition.(5)

EOR SECURITY INSURANCE PROGRAM*



***Assumptions:**

- Incremental EOR production for national security 1.4 MMbbl/day - 1990
- SPR capability reduced by Phase III Big Hill storage facility.

Figure 7

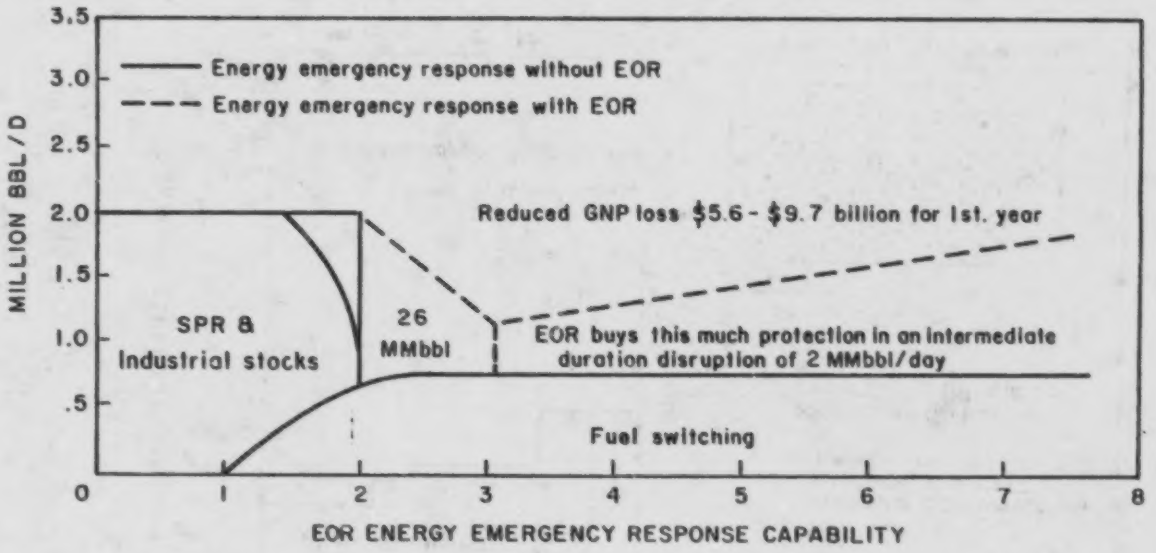

Energy emergency response without EOR
Energy emergency response with EOR
MILLION BBL/D
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
1
2
3
4
5
6
7
8
Reduced GNP loss $5.6 - $9.7 billion for 1st. year
SPR &
Industrial stocks
26
MMbbl
EOR buys this much protection in an intermediate
duration disruption of 2 MMbbl/day
Fuel switching
EOR ENERGY EMERGENCY RESPONSE CAPABILITY

Figure 8

- Incremental EOR Production increase at a rate of 200 Mbbl/day per year. This level of increase is substantially lower than preliminary estimates suggest as possible.
- SPR and industrial stocks are drawndown at a rate which will satisfy the shortfall until exhausted.
- Incremental EOR production is started immediately by industry in response to economic factors or Federal intervention.

The Congressional Budget Office (CBO) has estimated that for a 3.5 MMbbl/day interruption, each barrel of oil released from the SPR would reduce real GNP losses by $216 to $374 during the year of the shortfall.(13) Assuming this holds for the example, the EOR would reduce real GNP losses by $5.6 to $9.7 billion. The cost of the R&D program would be approximately $100 million.

Finally, as shown in Figure 5, the advanced EOR can provide a substantial increase in additional production by 1990 in non-emergency situations. This additional production will take place if the advanced technology is available and the information about its application is at hand when the economic conditions warrant. This increased production will reduce the nation's vulnerability to import interruptions.

COMPARISON OF R & D EXPENDITURES

	R & D as % sales	R & D as % profits	R & D as $ (billions)
Total Industry	2.0	38.2	28.1
High technology Industries			
Computers	6.4	64.1	3.4
Pharmaceuticals	4.9	51.3	2.3
Aerospace	4.5	124.6	2.0
Petroleum			
Fuel & Supply	0.4	6.6	1.5

Figure 9

4.0 Industry Investment in Advanced EOR

The structure and priorities of the U.S. petroleum extraction industry are unlikely to make EOR a significant factor in supply interruptions without the development of new information; moreover, this industry is likely to become considerably more concentrated as opportunities for smaller operators become more limited due to the absence of proven advanced extraction technology.

The U.S. petroleum extraction industry is mature and diverse. It can be characterized as being composed principally of two types of operators:

> Majors, which are multi-national, vertically-integrated corporations with exploration, production, refining, and marketing operations around the world, and independents, which are non-integrated producers of crude oil varying in size from a few people to multi-million dollar corporations with exploration and production operations primarily in the U.S.

The multi-national majors perform by far the vast majority of U.S. private petroleum research. Their R&D efforts, however, are limited by realistic assessment of critical economic factors. Figure 9 clearly shows that the petroleum fuel and supply industries invest significantly lower percentages of sales and profits in research than typical high technology industries. This practice results from a limited ability to recover R&D costs from operations of an individual company's properties or through patents or licenses. Long leadtimes, high risks, and high costs of fundamental R&D during times of high capital costs, combined with management criteria that emphasize near-term results impacts R&D expenditures. Private industry does invest in and conduct some EOR research; however, there are greater incentives for multi-nationals to acquire new reserves through exploration or outright purchase. Multi-nationals limit the size and budgets of their R&D efforts within these constraints, aggressively pursuing applied developmental engineering rather than fundamental research.

Independents, who produce nearly half the domestic oil, have limited venture capital to invest in more advanced technologies. They rely on the technical petroleum press, consulting engineers, and service companies to advise them on the latest technology developments. These organizations, in turn, also rely on publicly-available information. Independents, as shown in Figure 10, play a major role in exploration, development drilling, and production. Exploration development, and production opportunities available to independents are decreasing. The U.S. is a mature area for exploration -- the number of promising geological prospects is decreasing and the costs of finding new oil are rising; the major new domestic "plays" are mostly gas-prone. Independents often lack the expertise or investment base to pursue opportunities abroad. As a consequence, the independents are disproportionately more active in the regions where the majority of production has declined to the level of "stripper wells," Appalachia and the mid-Continent. The location of the majority of EOR projects tends not to be

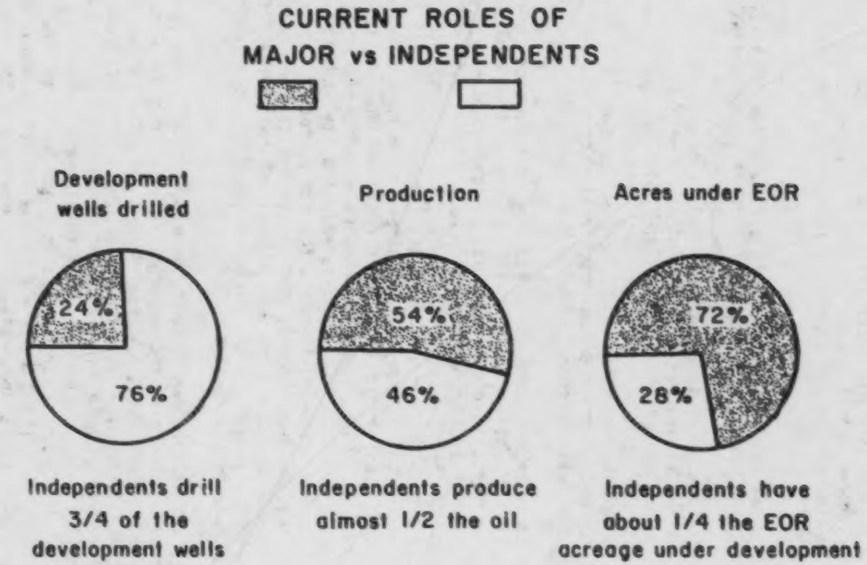

CURRENT ROLES OF
MAJOR vs INDEPENDENTS
▨
☐
Development wells drilled
24%
76%
Production
54%
46%
Acres under EOR
72%
28%
Independents drill 3/4 of the development wells
Independents produce almost 1/2 the oil
Independents have about 1/4 the EOR acreage under development

Figure 10

where production declines are most severe, but where the majors are most active, the Southwest and West. Due to present technology uncertainties and constraints, nearly 90% of these EOR projects employ currently available, but less effective EOR technologies. About 10% represent project using high yield, high risk approaches.

Thus, the structure of the domestic petroleum extraction industry is such that the multi-national majors have apparently better investment opportunities abroad, so limit their investment in EOR R&D and advanced application; independents have limited capability to invest in R&D and have limited access to new technologies. Both majors and independents will however apply available EOR technologies when the risks are justifiable and economic incentives are provided.

What makes this issue so important is that the use of less effective technology today frequently precludes the application of more effective processes when they do become available. First, once a field is committed to production using one EOR technology, the operator probably will not be willing to consider an alternative until reaching the economic limit. Second, a field may be so altered by the application of one EOR process that it may not be suitable for another.

5.0 The Federal Role in Advanced EOR Development

5.1 Existing R&D Program

DOE is in a unique position to assure that appropriate research is done in time to assure that backup is available when needed. Actual EOR potential must be evaluated from a national perspective to ensure that development is focused on those combinations of reservoirs and processes which can have the greatest impact. This analysis is a key part of the Federal role.

Previous government sponsored work provides data needed to define problems and develop solutions. Twenty-eight field projects targeted to different process/reservoir combinations are in a mature enough state to provide detailed data to analyze the discrepancies between predicted and actual performance. These field projects were cost-shared with industry, the Federal share averaging one-third the cost and the total investment exceeding $250 million. Some of these field projects are scheduled to run beyond the 1986-1987 period. In addition, more than 400 applications were reviewed under the DOE's Incentive Program which provided up to $20 million per project. The intent was to encourage tests of a variety of combinations. Thus, the U.S. already has a major national investment exceeding 1 billion dollars in EOR field projects available for study. Most of these are field trials which are still in operation and generating information. With the above results in hand, it is then possible to compare what needs to be done from the national perspective with what is actually being done by individual firms in pursuing their own interests.

The Federal Government's role is to improve the basis of understanding of EOR processes and to inject this information into the market. By virtue of being able to look across the full spectrum of work in the area, more data are available to the government program than to any individual research group. The twenty-six mature industry-government cost-shared projects provide the basis for the analysis of discrepancies between the predicted and actual performance. The basic research provides the knowledge base and understanding of the reservoirs and processes which then can be used to explain the discrepancies found and thus lead to improved theory. The hundreds of existing projects provide the "laboratory" to test the updated theory and conduct further discrepancy analyses and interpretations. Through this iterative procedure, processes can be developed which are predictable, and will work. This broader viewpoint is of great importance in leading to the accurate interpretation of technical problems and can only be assumed by the Federal Government.

The existing DOE program in EOR is based on a market-driven information strategy. With the public sponsored work generating and disseminating critically important but otherwise unavailable technical information, the mature petroleum industry is expected to apply the most advanced EOR technology that economic and other conditions warrant. In the absence of a supply emergency, this strategy will allow market forces to increase domestic production, thereby reducing vulnerability to supply interruptions.

The two key objectives of the current EOR program are (1) predictability (improved understanding with increase process control and reduced technological risk), and (2) recovery efficiency (higher portions of residual crude oil recovered). Figure 11 illustrates the program approach and logic. (It is not the intent of this paper to quantify the level of Federal support appropriate to conduct a vigorous EOR program).

Technology Appraisal is designed to provide overall assessment of the status of EOR technology. Its purpose is to assess EOR's predictability and recovery efficiency for all EOR processes against all reservoir types. Its main components are:

- Planning and management -- coordination of the Technology Appraisal function.
- Reservoir data and description -- development, updating, and maintenance of a file of reservoir properties representative of the domestic residual crude oil resource base.
- Process data and description -- development and updating of EOR project files and simplified EOR process models that reflect the state-of-the-art in EOR and the implications of alternative, feasible technology improvements; estimation of technically recoverable oil and recovery efficiency.
- Economic and logistical assessment -- development and maintenance of appropriate cost and supply models to assure that EOR R&D is pursued cost-effectively; i.e., focused on the highest priority reservoir situations.

In conjunction, these components address the overall predictability and recovery efficiency of EOR at a level that can assist in setting R&D goals and priorities or can lead to the conclusion that further R&D is unnecessary. As an adjunct, the Technology Appraisal function can provide estimates of future EOR production to public and private organizations whose planning requires this information.

Technology R&D reflects the priorities and constraints defined in Technology Appraisal. The specific programs for steam drive, carbon dioxide flooding, micellar-polymer flooding and more advanced processes share this general program logic. Generically, technology R&D consists of six components, all directed toward an improved theoretical understanding that would lead to acceptable process predictability and recovery efficiency:

- Planning and management -- analysis, planning, coordination, and direction of technology R&D.
- Process characterization and evaluation -- R&D to improve basic understanding of the behavior of EOR materials in the reservoir to characterize the fundamental mechanisms of residual oil displacement and mobilization and how these are affected by alternative process designs.

OVERALL LOGIC OF THE EOR PROGRAM

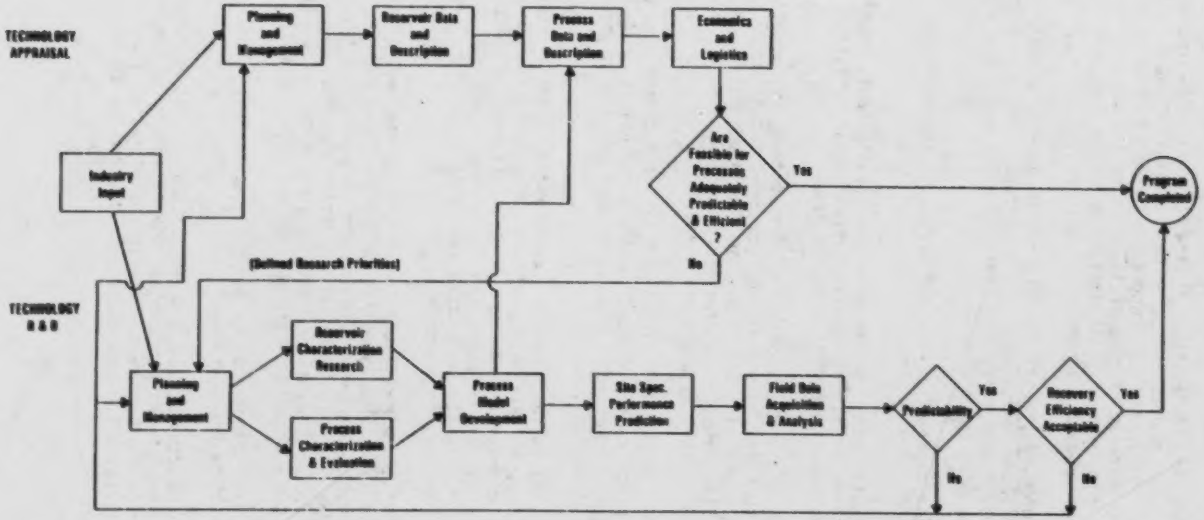

TECHNOLOGY APPRAISAL
Industry Input
Planning and Management
Reservoir Data and Description
Process Data and Description
Economics and Logistics
Are Feasible for Processes Adequately Predictable & Efficient ?
Yes
No
Program Completed
(Defined Research Priorities)
TECHNOLOGY R & D
Planning and Management
Reservoir Characterization Research
Process Characterization & Evaluation
Process Model Development
Site Spec. Performance Prediction
Field Data Acquisition & Analysis
Predictability
Yes
No
Recovery Efficiency Acceptable
Yes
No

Figure 11

- Geoscience research -- development of improved instruments, tests, and analytic procedures to describe the attributes of reservoir rocks and fluids essential to predicting EOR performance.
- Process model development -- detailed mathematical description of the performance of the process in the reservoir as a function of the properties of reservoir rocks and fluids and specific process designs -- in effect, the statement of the current theory of the respective EOR techniques -- for use in predicting process performance in specific settings.
- Site-specific performance prediction -- acquisition of site-specific data and analyses to make concrete, quantitative predictions of particular EOR process designs in specific reservoirs.
- Field performance appraisal -- collection and discrepancy analysis of field data to test the accuracy of the predictions. The purpose of discrepancy analysis is to account fully for variances between predictions and performance. The key issue is to explain which components of the predictive methodology, process, or reservoir characterization need to be improved to make performance both consistent with the predictions and acceptable overall. This element is actually an integral part of the three proceeding elements and also derives inputs from them. By knowing why a process did not work, further R&D can be planned. Poor understanding or measurement of the reservoir, faulty process design (indicating inadequate understanding of how the process works), insufficient modeling capability, or simply implementation errors can all contribute to unpredictable performance. The result of this work is a state-of-the-art in EOR application, in terms of recovery efficiency, technical risk and economic characteristics.

As shown in Figure 11, results of each program element are "fed back" to other elements to maintain the currency and direction of the R&D program.

The results, once available, are of great use to industry. Improved fundamental understanding will increase the predictability and, possibly, the control and recovery effectiveness of EOR processes. Increased predictability will shorten the R&D leadtime, reduce technical risks, and clarify the potential applicability and feasibility of specific process designs to individual reservoirs. Thus, improved understanding of advanced EOR technologies enhances them relative to individual firms' criteria for their own R&D as well as improves industry's information base in deciding whether to apply the advanced, more effective processes in the field.

5.2 Pre-Engineering Initiative

The foregoing summarizes the existing DOE EOR research program. Reduced vulnerability to interruptions is a direct result of the existing program. No specific "preparedness objective" for emergency EOR to mitigate an intermediate duration disruption is explicitly addressed. Addition of this objective to the EOR program's mission, however, can be done very cost-efficiently by "leveraging" the data bases, models, and basic research of the existing program. Technology Appraisal has developed data bases and models that will currently permit preliminary rank-ordering of fields and reservoirs for their applicability to rapid exploitation in an emergency at any stage of technology. These data and models are currently being validated in cooperation with the National Petroleum Council. The more detailed models, advanced reservoir description tools, and process characterizations of technology will permit detailed pre-engineering of the highest priority fields. As EOR technology is improved, both the rank-ordering and pre-engineering would be updated to currency with the state-of-the-art. More specifically, the "pre-engineering' portion of the "preparedness" strategy would include:

a. Screening and Strategic Planning

- o Definition of criteria by which possible process/reservoir combinations would be judged, probably a weighted mix of time to respond, quantity of response, quality of oil produced, and extraction costs under emergency conditions.

- o Rank-ordering of known fields against these criteria considering all relevant EOR processes as they currently perform and as they might perform under advanced technology. The former would provide a prioritization for early-stage pre-engineering; the latter would be a significant factor in establishing detailed R&D priorities under the "preparedness" objective.

- o Preparation of emergency response plans at the most detailed level practicable, to be updated continuously as more detailed data and new information become available; included would be logistics, economics, expected responses, and likely problems. In particular, these plans would include prioritization of key reservoirs to be included in the more costly steps b and c below.

b. Planning/Design

Collection and interpretation of more detailed reservoir data on the highest priority, near-term reservoirs. This would prepare the basis for more detailed petroleum engineering feasibility assessments based on the available reservoir simulators and alternative EOR process designs, and would result in further prioritization of candidate reservoirs and specific, detailed plans for pilot testing. A degree of cost sharing is expected in this step.

c. Pilot Testing

Possible pilot testing in the highest priority reservoirs on a very small scale to validate the feasibility of the designs;

such tests would also serve the evolving basic research need for field data. The pilot tests would either accelerate EOR development or would establish whether the reservoir could be relied upon to contribute to an emergency response.

d. Updating

Updating steps a, b, and c as technology improvements become available and more substantial experience with advanced EOR processes provides data.

The "product" of these efforts would be a current emergency plan that would describe concrete measures for accelerating EOR as an insurance backstop to SPR for supply emergencies of intermediate duration. The pre-engineering would have two desirable results:

- o Reservoir/process combinations found to be economically attractive would be further evaluated by the field operators and many new EOR projects would be initiated, accelerating EOR applications and reducing the nation's vulnerability to import disruption.

- o The nation would have an up-to-date, concrete program for accelerating EOR production in times of emergency, permitting a graduated, geographically dispersed response that might include such micro-economically suboptimal but macro-economically necessary approaches as over-engineered EOR processes, closely-spaced wells, etc., in the context of compensation arrangements that would fairly reimburse all interested parties.

6.0 Program Cost/Benefit Analysis

The Federal R&D program outlined in Section 5 would reduce the risk associated with the advanced EOR technologies and lead to industrial investment in these processes while increasing national preparedness to mitigate intermediate-duration interruptions. As previously shown in Figure 5, the expected additional contribution from advanced technology through the year 2000 in the absence of a supply emergency would be:

EOR PRODUCTION, 1983 - 2000, ADVANCED CASE

Year	Incremental Productive Rate MMbbl/Day	Incremental Productive Rate MMbbl/Year	Cumulative Production MMbbl
1985	0.5	225	505
1990	1.4	510	2525
1995	2.0	730	5780
2000	2.7	985	10250

An all-inclusive Federal R&D program of about $25 million per year in R&D funds is assumed as a base for cost-benefits analysis. (The numbers for R&D outlays assumed in this section are not to be interpreted as a request for DOE funding in excess or below DOE budgetary actions but rather as a convenient number with which to normalize the cost-benefits statements. Further, direct R&D outlays may be offset by other mechanisms such as tax incentives.) The additional oil produced by the advanced processes, on the other hand, would result in significant tax gains to the government via income taxes and the Windfall Profit Tax (WPT). Based upon the expected additional production of 10.25 billion barrels by the year 2000, the following table shows the estimated ratio of tax gains to R&D outlays from 1983 to 2000:

ESTIMATION OF TAX GAINS TO TAX OUTLAYS
(Present Value 1983 - 2000)

Discount Rate (%)	Tax Gain ($ Mill.) ($3.60-$5.10/Bbl)*	Program Cost (Avg. $25 Mill./yr)	Ratio of Tax Gain to Program Cost
0	$36,900-52,280	$425	87-123
5	20,160-28,560	280	72-110
10	11,800-16,830	200	59-84

* Lower rate assumes no WPT; higher rate assumes WPT throughout period.

The return to the treasury in tax gains versus outlays resulting from the Federal R&D program is highly positive, 60 or more-to-1, even in the absence of a supply shortfall, and would be much higher should an emergency develop.

Finally, a Federal program could lead to an incremental contribution to the nation's petroleum supply in time to offset the need for the Big Hill SPR storage addition. This could reduce the Federal outlay by up to $915 million in nominal dollars excluding the cost of 140 MMbbls of oil which would be purchased. The investment of $175 million in advanced EOR research and development by 1990 would appear small in comparison.

7.0 Conclusions

- SPR is primary defense against crude oil shortfall:

  Costs \$1.325 billion in FY 1974 (Based on FY 83 Estimate).(4)

  Provides in 1990 about 4-1/2 million barrels per day for 5-1/2 months.

- Advanced EOR could, by 1990, result in incremental production of oil sufficient to offset the need for the Big Hill SPR storage addition.

  Advance EOR incremental production could provide up to 1.4 million barrels per day in long-term supply by 1990.

  Big Hill storage supplies 0.935 million barrels per day.

  Big Hill storage will cost up to \$915 million excluding cost of oil; the cumulative R&D costs of advanced EOR will be considerably less.

- EOR provides long-lasting backup through market mechanism:

  R&D leverages private sector investment.

  Provides in 1990 a total of about 2.1 million barrels per day rising to over 3.3 million barrels per day by 2000.

  Production rates could be even higher in national emergency.

  Return to U.S. Treasury from advanced EOR research is at least 60:1 or better in taxes.

- EOR research will:

  Improve predictability of processes.

  Increase oil yield per dollar investment.

  Extend application to more reservoir settings.
  Provide information for prudent private investment.

  Allow identification and pre-engineering of reservoirs and thus reduce response time for emergency application of EOR.

  EOR research has special benefits to independents.

  EOR research is prudent public investments.

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April 7, 1983

ENHANCED OIL RECOVERY AS AN ELEMENT IN STRATEGIC PETROLEUM PREPAREDNESS

PURPOSE

An earlier paper, "Enhanced Oil Recovery: A key to National Security," proposes that enhanced oil recovery (EOR) could be regarded as a highly cost-effective complement to the Strategic Petroleum Reserve in reducing vulnerability to import interruption of an intermediate duration. Positioning EOR to play this role requires a strategy combining the following:

- A program of market-oriented research and development aimed at producing the information needed to increase the predictability, reliability, and yield of EOR; with
- A program of pre-engineering of selected fields to minimize the delay of an EOR response in a national emergency.

This paper provides analytical background for the earlier paper. It summarizes the following components of the proposed strategy:

- The phases and activities required to initiate EOR production, any or all which could be part of a pre-engineering program;
- The time-frame of EOR response under emergency conditions;
- Estimates of the costs of EOR production, both with and without advanced technology, (resulting from R&D) under conventional and emergency conditions;
- The feasibility of EOR meeting specified target levels of production under emergency conditions; and
- An outline of the pre-engineering component of the program.

PHASES AND ACTIVITIES REQUIRED TO INITIATE EOR PROJECTS

Exhibit 1 displays the basic phases and their constituent activities from the inception of planning an EOR project to the beginning of actual application. The time estimates are based on a recent study by Texaco, Inc. and our experience with cost-shared field tests: ranges are shown for each phase and activity. Because many activities within a given phase can be conducted concurrently, the phase estimates are often less than the sum of the activity estimates. The phases, however, are generally additive, each being a necessary precursor to the next. In summary, the required phases up to the injection of EOR fluids are as follows:

PHASES	TIME, MONTHS
1. Screening to select the EOR process that is most appropriate to the properties of the specific reservoir under consideration.	3-9

41

2. Planning/Design/Approval to develop detailed process design and performance predictions in light of carefully studied reservoir data.	6-18
3. Pilot Construction to drill and work over the necessary wells, and to prepare all surface facilities.	8-30
4. Conduct Pilot to test the detailed design, to assess discrepancies between predicted and actual performance, and to prepare scale-up plans based on this assessment.	16-60
5. Field-Scale Construction to prepare the wells and surface equipment for the first segment of full-field EOR implementation.	10-30
TOTALS	43-147

The minimum in this range is unlikely but possible. The maximum would result from a series of delays and unforeseen problems; no company would plan to take more than 12 years to begin injection. The probable range is estimated at 60-100 months. At the conclusion of any phase (except the last), the reservior can be rejected as an EOR candidate due to unacceptable predicted or actual technical performance or unfavorable economics.

TIME FRAME OF EOR RESPONSE TO AN IMPORT SHORTFALL

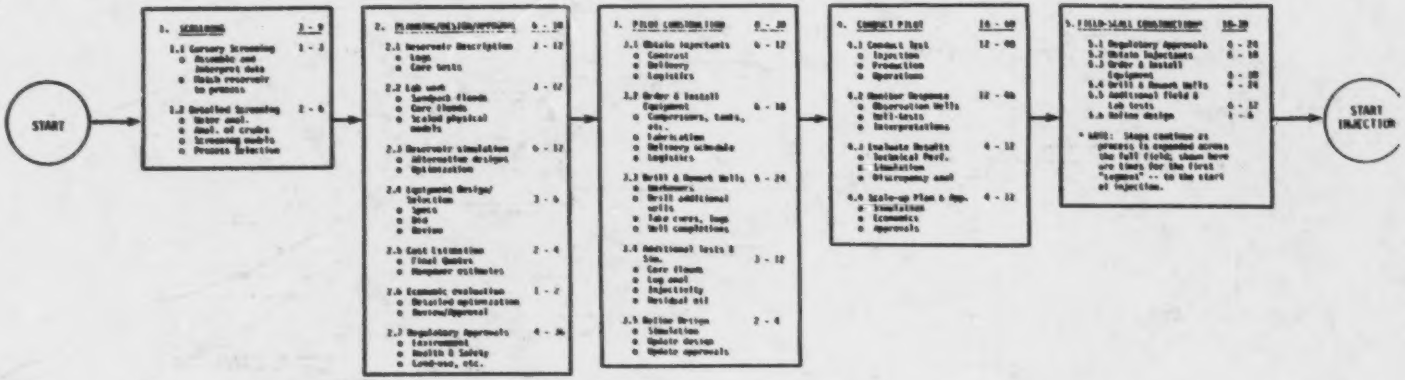
The timing of EOR response to an interruption in imports depends heavily on the stage of development of the reservior relative to EOR production. Exhibit 2 illustrates that response times can range from nearly instantaneous to more than 8 years, depending on the number of pre-production phases that have been completed. (Attachment 1 shows the quantitative assumptions used in Exhibit 2.)

The respective stages of development could be the result of market factors having stimulated operators' interest in EOR or could result from pre-engineering work completed up to a particulat point in the interests of national security. The Exhibit displays seven states of preparedness and estimates the time to respond from the point of a "signal" that EOR is needed to offset a portion of an import shortfall to actual production. In this sense, each could be the component of an EOR preparedness strategy, depending on the extent of pre-engineering provided; thus, the title, "Idealized Order of Commitment."

- Class A fields are those already under full field development, so they are reducing vulnerability by offsetting the rate of decline in production from conventional oil recovery technology. Note that the pre-engineering that demostrates economic viability could stimulate operators to create Class A fields earlier than they might without the pre-engineering. Class A fields can also be considered in Class C.

EXHIBIT 1

STEPS IN DEVELOPING AN EOR PROJECT FROM INCEPTION TO START OF INJECTION*

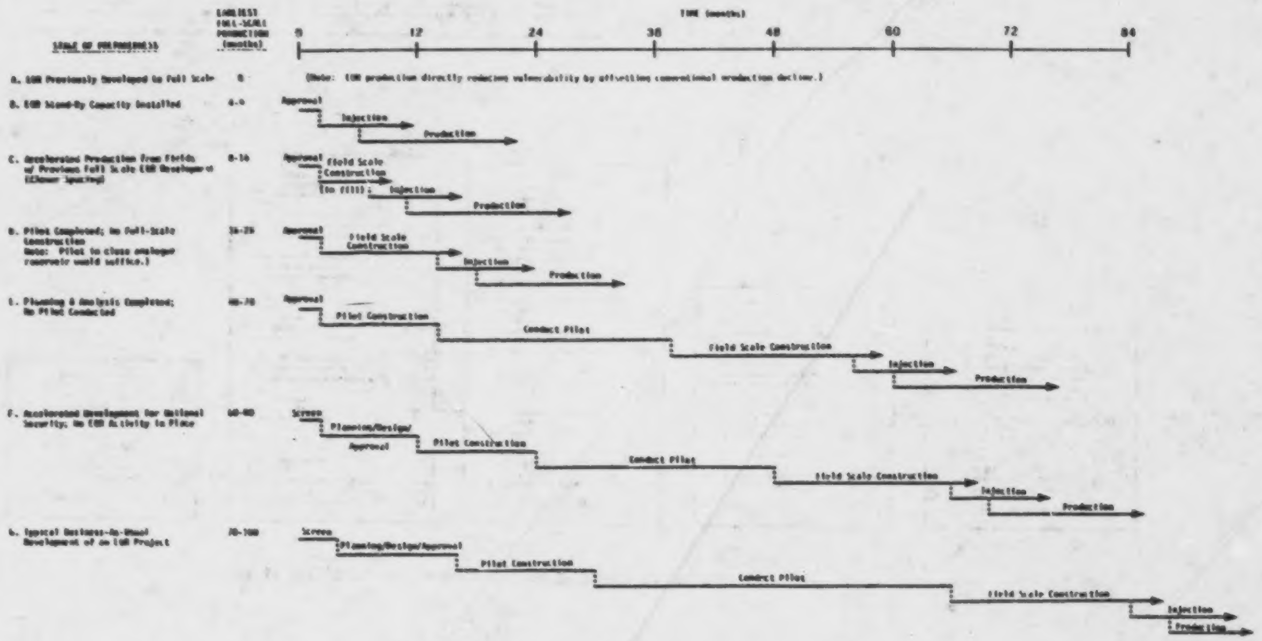

START
1. SCREENING 3 - 9
1.1 Cursory Screening 1 - 3
o Assemble and interpret data
o Match reservoir to process
1.2 Detailed Screening 2 - 6
o Water anal.
o Anal. of crudes
o Screening models
o Process Selection
2. PLANNING/DESIGN/APPROVAL 6 - 30
2.1 Reservoir Description 3 - 12
o Logs
o Core tests
2.2 Lab work 3 - 12
o Sandpack floods
o Core floods
o Scaled physical models
2.3 Reservoir simulation 6 - 12
o Alternative designs
o Optimization
2.4 Equipment Design/Selection 3 - 6
o Specs
o Bid
o Review
2.5 Cost Estimation 2 - 4
o Final Quotes
o Manpower estimates
2.6 Economic evaluation 1 - 2
o Detailed optimization
o Review/Approval
2.7 Regulatory Approvals 4 - 36
o Environment
o Health & Safety
o Land-use, etc.
3. PILOT CONSTRUCTION 8 - 30
3.1 Obtain Injectants 6 - 12
o Contract
o Delivery
o Logistics
3.2 Order & Install Equipment 6 - 18
o Compressors, tanks, etc.
o Fabrication
o Delivery schedule
o Logistics
3.3 Drill & Rework Wells 5 - 24
o Workovers
o Drill additional wells
o Take cores, logs
o Well completions
3.4 Additional Tests & Sim. 3 - 12
o Core floods
o Log anal
o Injectivity
o Residual oil
3.5 Refine Design 2 - 4
o Simulation
o Update design
o Update approvals
4. CONDUCT PILOT 16 - 60
4.1 Conduct Test 12 - 48
o Injection
o Production
o Operations
4.2 Monitor Response 12 - 48
o Observation Wells
o Well-tests
o Interpretations
4.3 Evaluate Results 4 - 12
o Technical Perf.
o Simulation
o Discrepancy anal
4.4 Scale-up Plan & App. 4 - 12
o Simulation
o Economics
o Approvals
5. FIELD-SCALE CONSTRUCTION* 18-30
5.1 Regulatory Approvals 6 - 24
5.2 Obtain Injectants 6 - 18
5.3 Order & Install Equipment 6 - 18
5.4 Drill & Rework Wells 6 - 24
5.5 Additional Field & Lab tests 6 - 12
5.6 Refine design 1 - 6
* NOTE: Steps continue as process is expanded across the full field; shown here are times for the first "segment" -- to the start of injection.
START INJECTION

* Times shown in months; individual task activities do not add to phase totals because of simultaneous achievement.

Adapted from [illegible], "New Study Gives Time Frame Estimates for Large-Scale Commercial Application of EOR," Oil and Gas Journal, April 26, 1982, pp. 140-149; and actual experience in federal-industry cost-shared tests.

EXHIBIT 2

IDEALIZED ORDER OF COMMITMENT OF EOR PROJECTS UNDER EMERGENCY CONDITIONS



- Class B fields have stand-by EOR capacity delivered and installed but unused. This would be an extreme form of "pre-engineering." It is not recommended, but is included as a possible option for massive emergency response. Probably such fields would be economically marginal, otherwise the market would have made these Class A fields.

- Class C fields are those Class A fields in which EOR can be accelerated by reducing the pattern size of the EOR processes. Shorter distances between wells will accelerate production (and might increase total recovery slightly) at the cost of the additional wells. Reducing EOR pattern size by half would result in 30 percent faster recovery; reducing spacing by one-fourth would increase the production rate by 50 percent. Th costs of the additional wells would however, increase the cost of the EOR production.

- Class D fields have completed pilot testing and planning for full scale development of EOR. They may be one of two types:

  1. Those for which a pilot test has demonstrated economic viability -- awaiting only the financial or logistical capacity to become Class A fields, and

  2. Those for which the pilot has demostrated marginal economics -- highly useful in an emergency, but not likely to become Class A fields under prevailing, non-emergency economics.

  Class D fields of the second type could be a key component of an EOR strategy to deal with real emergencies of intermediate duration. An actual pilot test in all Class D field would not necessarily be required. A field could become a Class D field of either type based on limited reservoir testing and laboratory work and a competent pilot test in a directly analogous reservoir in another field.

- Class E fields are those for which the screening and planning phases have been completed but no pilot has been conducted. These would be a further fallback should the emergency be prolonged.

- Classes F and G are fields for which no EOR pre-engineering work has been conducted. They differ only in that Class G illustrates "business as usual" timing, whereas Class F accelerates the pre-injection work. Class F also illustrates the time-frame that could be expected from a "start point" for a federal program of pre-engineering. In brief, slightly more than 5 years would be required to convert a field from Class F to Class A, B, or C.

Fields of all these classes could be components of an EOR emergency preparedness, pre-engineering strategy that rationally balances EOR costs, timing, response magnitude, logistics, etc. Clearly, considerable analysis is required to gather the data and study the compromises necessary to produce a viable national strategy.

COSTS AND RESPONSE TIMES OF EOR PROCESSES

Exhibits 3A, B, and C summarize the analysis for carbon dioxide flooding, steamflooding, and surfactant flooding, respectively. In all three cases, a typical, relatively good reservoir was hypothesized. Since the specific reservoir properties are based on EOR projects currently underway, they are more realistic than the "average" properties of all reservoirs that might be considered EOR candidates. The screening and analyses that are part of a pre-engineering program would identify better-than-average reservoirs. (Attachment B shows the reservoir properties used in the analysis.)

Consistent with the analysis in the earlier paper, two levels of technology performance were hypothesized.

1. Base case, which is the performance level achievable with technologies currently available or currently under development by industry _if_ they could be made to perform as predicted (which would itself require additional R&D) and

2. Advanced case, which is the performance level achievable through R&D efforts over and above those presently included in industry's plans (the subject of the R&D component of the overall "preparedness" program for EOR).

The most useful standard unit of analysis of an EOR process is the pattern -- often one injection well with four or more producing wells. Pattern size is usually defined in terms of acres per well. As noted, EOR production can be accelerated by reducing the pattern size. To examine the effect of reducing pattern size, the additional analysis was conducted for two pattern sizes: typical spacing for the respective EOR processes and one-half typical spacing (which reduces the distance between injection and producing wells to approximately 70 percent of the distance of the typical pattern size).*

These two sets of analyses result in the four analytical scenarios (two technology cases by two pattern sizes) shown at the top of each of the three parts of Exhibit 3. Each scenario was analyzed to determine the net present value cost of EOR production and the corresponding production rates for one pattern at typical spacing or two patterns at half-spacing (the equivalent reservoir volume). The resulting costs per barrel of EOR estimates are summarized below:

NET PRESENT VALUE COST PER BARREL OF EOR
(1983 dollars)

	Base Technology		Advanced Technology	
	Typical Spacing	1/2 Typical Spacing	Typical Spacing	1/2 Typical Spacing
Carbon Dioxide	29	34	24	28
Steam	25	33	18	24
Surfactant	36	41	29	33

---

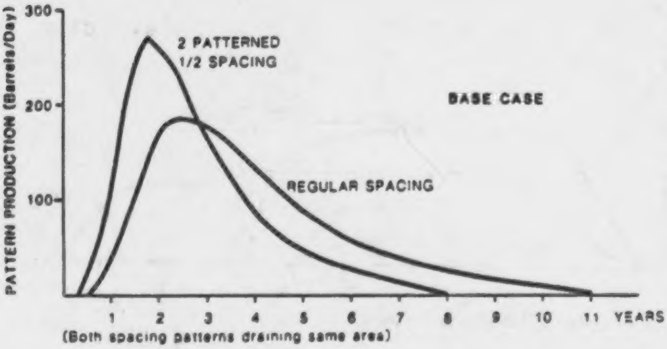
* Still closer spacings are possible. Half-typical was chosen for convenience and because it would be a reasonably conservative step in an emergency.

Exhibit 3A

CO_2 - ENHANCED OIL RECOVERY

MINIMUM PRODUCTION COST PER BARREL
($/Barrel)

	REGULAR SPACING (40 ACRES/WELL)	HALF SPACING (20 ACRES/WELL)
BASE CASE	29	34
ADVANCED CASE	24	28



(Both spacing patterns draining same area)

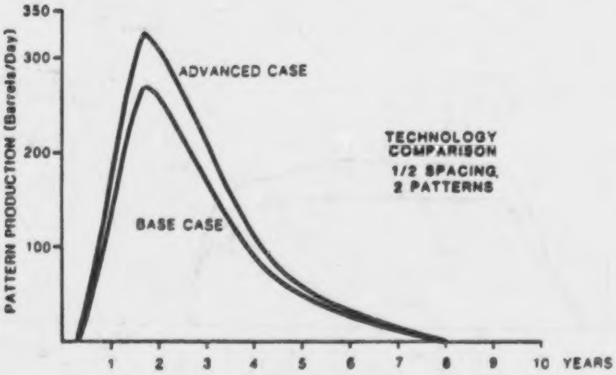
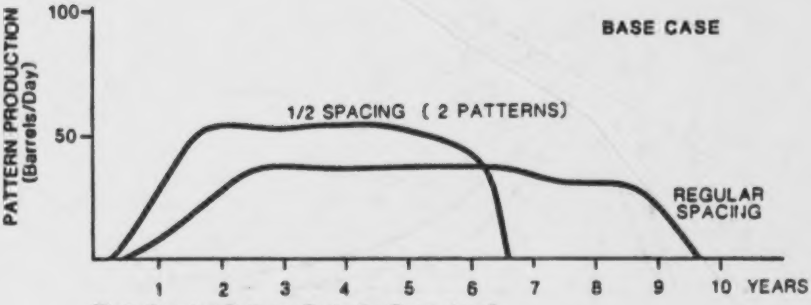


Exhibit 3B

STEAM - ENHANCED OIL RECOVERY

MINIMUM PRODUCTION COST PER BARREL
($/Barrel)

	REGULAR SPACING (2.5 ACRES/WELL)	HALF SPACING (1.25 ACRES/WELL)
BASE CASE	25	33
ADVANCED CASE	18	24



(Both Spacing Patterns Drain the Same Area)

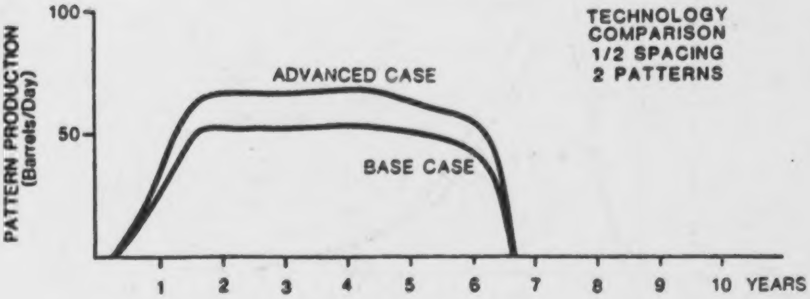
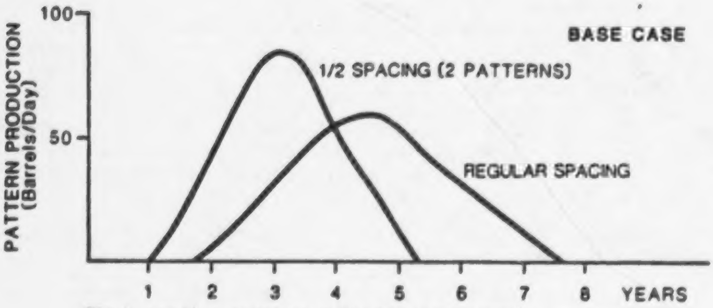


Exhibit 3C

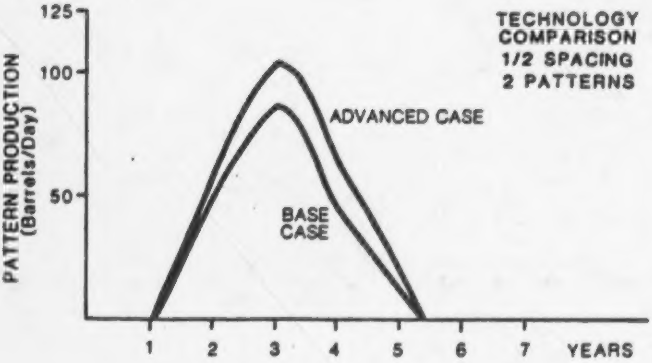
SURFACTANT-ENHANCED OIL RECOVERY

MINIMUM PRODUCTION COST PER BARREL
($/Barrel)

	REGULAR SPACING (5 ACRES/WELL)	HALF SPACING (2.5 ACRES/WELL)
BASE CASE	36	41
ADVANCED CASE	29	33



(Both spacing patterns drain the same area)



Although these results are only exemplary of the better reservoirs for each process, they are reasonably typical.* All the cost calculations are within the range that would be considered "reasonable," especially under the conditions of an import shortfall. Under Base technology and typical spacing, the three processes rank as expected, with steam lowest in cost, carbon dioxide next, and surfactant cost highest. This relationship is reflected in actual field projects now in operation.

Under both technology cases, closer spacing adds to the costs of EOR. Reducing the acres per well from typical (near optimal) to one-half of typical increases EOR costs $4-8 per barrel, depending on the case studied. The gain for this additional cost is more rapid response, as shown in the upper sets of curves in the three parts of Exhibit 3. For all three EOR processes, the response is earlier and higher for the same total reservoir volume with the samller pattern sizes.

Over both pattern sizes and all three EOR processes, the difference between Base and Advanced technology cases is reduced cost in the range $5-9 per barrel for the Advanced case. This cost reduction is one of the principal benefits of R&D to achieve the Advanced case.** The difference between the two levels of technology was assumed for this analysis to be improvements in the sweep eddiciency of EOR resulting in more oil produced per barrel of injected material. The lower sets of curves in the three parts of Exhibit 3 show how the Advanced case increases and accelerates production compared to the Base technology.

Finally, although the costs are only illustrative, it is notable that the Advanced case costs at reduced spacing are uniformly lower than the Base case at typical spacing, underlining the importance of the R&D component of the EOR preparedness strategy.

Thus, the analysis of the principal EOR processes in three typical-to-better reservoirs shows that:

- EOR production costs are in the relevant range, considering an interruption in imports,
- Emergency response can be accelerated and costs reduced by decreasing EOR pattern size (which raises the cost per barrel); and
- Emergency response can be accelerated and costs reduced by developing the improved technologies represented by the Advanced case.

---

* One limitation to the analysis of minimum economic costs is that expenses which are a function of selling price or profit (e.g., royalty and many taxes) can exaggerate differences in minimum costs as estimated. For example, royalty of 12.5 percent would be estimated in the above calculation at $3.125 in the cost of a $25 barrel of oil. If that oil were actually sold for $30, actual royalty would be $3.75.

** Although as noted in the above footnote, these cost differences are exaggerated somewhat by the method of calculating EOR costs per barrel.

FEASIBILITY OF EOR TO OFFSET IMPORT SHORTFALLS

Exhibit 4 shows four illustrative scenarios of EOR responses to import disruption. The four correspond to the scenarios in the analyses of the individual reservoirs, above. The curves all begin at the "Start of Injection."* In all four cases, it was assumed that the required EOR acreage would be divided evenly between the three processes. Each scenario was constructed by calculating the number of patterns needed to reach a target of 385 thousand barrels per day -- equivalent to producing 140 million barrels in 1 year -- within 1 to 1 1/2 years from the start of injection.

Because of the shapes of the production curves of the individual patterns (see Exhibits 3A, B, and C), production continues to increase after the target rate of production is achieved, in all cases reaching or exceeding 1 million barrels per day at the peak, before beginning to decline. The sharp decline is the direct result of the assumption that no new patterns are being added after the start-up of sufficient patterns to meet the target. In reality, new patterns would be phased in as needed to prolong production at whatever rate was deemed appropriate in light of economic and security conditions.

As an indicator of whether such a response if feasible, the percentage of the acreage required for the response has been related to the acreage in the 10 largest U.S. reservoirs for which each of the respective EOR processes has been determined to be suitable (30 reservoirs in all).**

In all four scenarios, the required acrage would appear to be feasible, assuming adequate planning and preparation. In the worst case (steam drive in Scenario 1), only 17 percent of the acreage in the 10 largest fields would be required.

o Scenario 1. Base technology at typical spacing is the least efficient means of meeting the EOR production target, requiring a total of 114,000 acres.

o Scenario 2. Advanced technology with typical spacing shows the contribution of increased sweep efficiency in meeting the target; again stressing the value of continued R&D. It requires only 78,000 acres, or 68 percent of the Scenario 1 requirement.

o Scenario 3. Base technology at half-spacing is also more effective than Scenario 1, requiring 81,000 acres (71 percent of Scenario 1), but production costs are as much as $7 per/barrel higher. Scenario 3, however, is less effective than Scenario 2, where technology improvement is incorporated.

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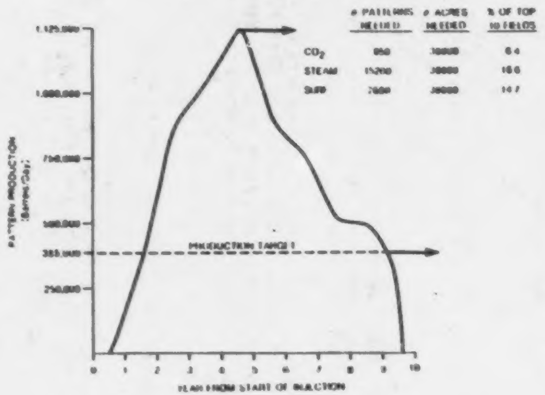
* Note the timing and conditions of "Start of Injection" in Exhibits 1 and 2.

** This suitability was determined by a preliminary screening of the EOR reservoir database, which contains essentially all of the largest U.S. reservoirs.

Exhibit 4

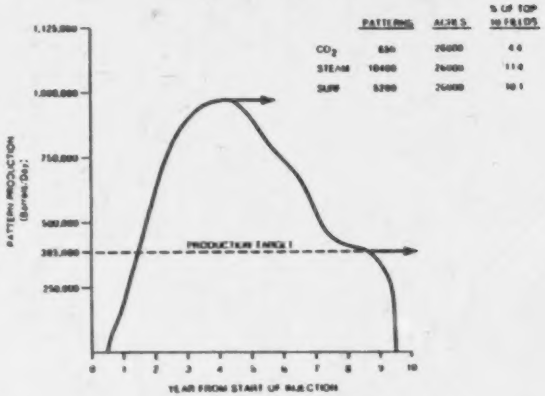
ILLUSTRATIVE SCENARIOS OF EOR RESPONSE TO IMPORT DISRUPTIONS

SCENARIO 1: BASE CASE-REGULAR SPACING



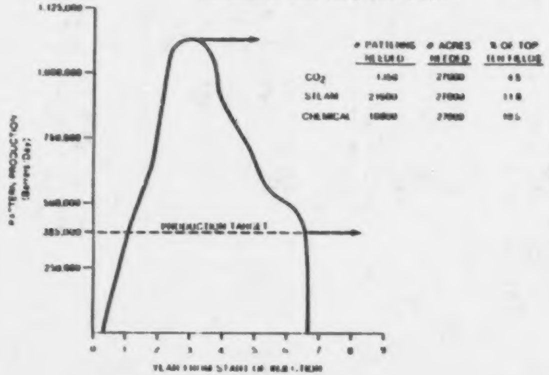
	# PATTERNS NEEDED	# ACRES NEEDED	% OF TOP 10 FIELDS
CO_2	850	30000	6.4
STEAM	15200	30000	16.6
SURF	7600	30000	14.7

SCENARIO 2: ADVANCED CASE-REGULAR SPACING



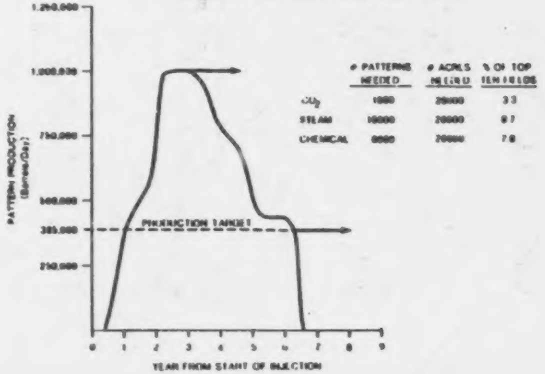
	PATTERNS	ACRES	% OF TOP 10 FIELDS
CO_2	680	26000	4.4
STEAM	10400	26000	11.4
SURF	5200	26000	10.1

SCENARIO 3: BASE CASE-HALF SPACING



	# PATTERNS NEEDED	# ACRES NEEDED	% OF TOP TEN FIELDS
CO_2	1,350	27000	4.5
STEAM	21600	27000	11.8
CHEMICAL	10800	27000	10.5

SCENARIO 4: ADVANCED CASE-HALF SPACING



	# PATTERNS NEEDED	# ACRES NEEDED	% OF TOP TEN FIELDS
CO_2	1000	20000	3.3
STEAM	16000	20000	8.7
CHEMICAL	8000	20000	7.8

- Scenario 4. Advanced case with half spacing is the most effective of the four sceneries in terms of acres required, 60,000 or 53 percent of the Scenario 1 requirement. The required 20,000 acres for each process could be met by any one of:

  --the ten largest carbon dioxide reservoirs,
  --the six largest steam drive reservoirs, and
  --the five largest surfactant flood fields.

  The cost of accelerating the Advanced technology case by smaller pattern sizes, however, varies from $6 to $9 per barrel, depending on the EOR process.

Thus, this illustrative example proposes that EOR can feasibly meet significant production targets in an import disruption of intermediate duration. It does require that sufficient screening, planning, and engineering by completed in advance, so that the point of "Start of Injection" can be held to within a year or so after the beginning of the import shortfall. In the terms used earlier, the immediate response would require pre-engineering of enough reservoirs to place them in Classes A, B, C, or D. Reservoirs in Classes E, F, and G would provide longer term potential EOR production.

This analysis also suggests that an EOR preparedness strategy would not entail an impossibly large number of acres or individual reservoirs. Logistical problems of wells, equipment, manpower, and injectants would need serious study, but planning and analysis could focus on a reasonably small number of carefully selected candidate reservoirs.

OUTLINE OF THE PRE-ENGINEERING COMPONENT OF EOR

The analyses presented above contain a large number of assumptions and implicit compromises. Optional positioning of EOR to complement strategic storage objectives would require in-depth feasibility studies, planning, reservoir data collection, screening, and related studies. Fortunately, we have developed databases and models that will currently permit preliminary rank-ordering of candidate fields and reservoirs amendable to EOR processes and which could be rapidly exploitated in an emergency. These data and models are currently being validated in cooperation with the National Petroleum Council. The more detailed models, advanced reservoir description tools, and process characterizations of EOR technology that are part of BETC's R&D program will permit detailed pre-engineering of fields having the highest rankings. As EOR technology is improved, both the rank-ordering and pre-engineering would be updated. More specifically, the "pre-engineering" portion of a "preparedness" strategy would include the following:

a. Screening and Strategic Planning

   - Definition of criteria by which possible process/reservoir combinations would be judged, probably a weighted mix of time to respond, quantity of response, quality of oil produced, extraction costs, and logistics under emergency conditions.

- Rank-ordering of known fields against these criteria considering all relevant EOR processes as they currently perform and as they might perform under Advanced technology. The former would provide a prioritization for early-stage pre-engineering, the latter would be a significant factor is establishing detailed R&D priorities the preparedness" objective.

- Preparation of emergency response plans at the most detailed level practicable, to be updated continuously as more detailed data and new information become available; this would include logistics, economics, expected responses, and likely problems. In particular, these plans would prioritize the key reservoirs to be included in the more costly Steps b and c, below.

b. Planning/Design

- Collecting and interpretation of more detailed reservoir data on the highest priority, near-term reservoirs to prepare the basis for more detailed petroleum engineering feasibility assessments. These would be based on available reservoir simulators and alternative EOR process designs. This would result in further prioritization of candidate reservoirs and specific, detailed plans for pilot testing. A degree of cost-sharing is expected in this step.

c. Pilot Testing

- Possible pilot testing in the highest priority reservoirs, cost-shared with the field's operator, on a very small scale to validate the feasibility of the designs. Such tests would also serve the evolving basic research need for field data. The pilot test would either accelerate EOR development or establish whether the reservoir could be relied upon to contribute to an emergency response.

d. Updating

- Updating Steps a, b, and c as technology is improved and more thorough understanding of EOR processes is gained.

Only a rough approximation of the scope of such a pre-engineering program can be made before accomplishing the detailed planning that is included in Step a. Rough estimates of the minimum dollar requirements for the program are as follows:

Estimated Cost (in millions of 1983 $)

	Year						
STEPS	1	2	3	4	5	6	7
a. Screening (and Strategic Planning) and d. Updating	1.0	0.5	0.5	0.5	0.5	0.5	0.5
b. Planning/Design		4.5	3.0	2.0	1.0	0.5	0.5
c. Pilot Testing	___	___	1.5	2.5	3.5	4.0	4.0
TOTAL	1.0	5.0	5.0	5.0	5.0	5.0	5.0

The preliminary studies suggested would require about $1 million in the first year, after which follow-up studies, plan updates, etc., would require about $0.5 million per year for the life of the project. Beginning in the second year, the Planning/Design phase for the highest priority reservoirs could be initated. Assuming some cost-sharing in this effort by the operators of these fields, the most promising 10 to 15 reservoirs could be studied at a cost of about $4.5 million. The next most promising 7 to 10 reservoirs could enter this phase in the third year at a cost of about $3.0 million, with initation of cost-shared Pilot Testing at the same time for the most promising one or two fields studied during the previous year. In year 4 and later, Pilot Testing is increased, and the Planning/Design work is reduced. In all, some 25 to 40 priority reservoirs would be studied in detail, with cost-shared pilot tests in 6 to 10. These are rough estimates, as noted. They assume extensive cost-sharing with the operators of the selected fields. The budget requirement would be higher without cost-sharing. One result of the first year's analytic effort would be an overall appraisal of feasiblity and, if positive, a more precise estimate of the number of targets and time requirements.

The "product" of these efforts would be a current emergency plan that would describe concrete measures for accelerating EOR as an insurance backstop to the SPR for supply emergencies of intermediate duration. The pre-engineering would provide these two desirable results:

1. Reservoir/process combinations found to be economically attractive would be further evaluated by the field operators, and many new EOR projects would be initated, accelerating EOR applications and reducing the Nation's vulnerability to import disruption, i.e., creating Class A, C, and D fields, and

2. The Nation would have an up-to-date, concrete program for accelerating EOR production in times of emergency, permitting a graduated, geographically dispersed response that might include such micro-economically suboptional but macro-economically necessary approaches as over-engineered EOR processes, closely-spaced wells, etc., in the context of compensation arrangements that would fairly reimburse all interested parties.

ATTACHMENT A

ESTIMATED TYPICAL TIMING AND COSTS

OF EOR INITIATION AT VARIOUS PHASES OF DEVELOPMENT

(Time in Mo.)

	IF NO EOR IN RESERVOIR						IF ANALYSIS & PLANNING COMPLETED-- NO PILOT	IF PILOT COMPLETED	IF EOR FULL-SCALE IN FIELD (CLOSER SPACING)	IF EOR INCREMENT PRE-CONSTRUCTED (STAND-BY) CAPACITY
	TYPICAL BUSINESS AS-USUAL		ACCELERATED FOR NATIONAL SECURITY		TYPICAL COSTS ($mm)					
	DUR	CUM	DUR	CUM	ITEM	CUM				
1. SCREENING	4	4	2	2	100	100				
1.1 Cursory Screening										
1.2 Detailed Screening										
2. PLANNING/DESIGN/APPROVAL	12	16	10	12	600	700	2			
2.1 Reservoir Description										
2.2 Laboratory Work										
2.3 Reservoir Simulation										
2.4 Equipment Design/Selection										
2.5 Cost Estimation										
2.6 Economic Evaluation & Approval							(2)			
2.7 Regulatory Approvals										
3. PILOT CONSTRUCTION	14	30	12	24	6000	6700	12			
3.1 Obtain Injectants										
3.2 Order & Install Equipment										
3.3 Drill & Rework Wells										
3.4 Additional Tests & Simulation										
3.5 Refine Design										
4. CONDUCT PILOT	36	66	24	48	1000	7700	24		1	
4.1 Conduct Test										
4.2 Monitor Response										
4.3 Evaluate Results										
4.4 Scale-Up Plan & Approvals								(2)	(1)	(1)
5. FIELD-SCALE CONSTRUCTION	18	84	18	66	Varies widely with design & spacing (included in process-economics analysis)		18	12	6	
5.1 Regulatory Approvals										
5.2 Obtain Injectants										
5.3 Order & Install Equipment									(6)	
5.4 Drill & Rework Wells									(6)	
5.5 Additional Field & Lab Tests										
5.6 Refine Design									(2)	(2)
START INJECTION		84		66			56	14	7	2

ATTACHMENT B

INPUTS TO THE EOR MODELS

	CO_2	STEAM	SURFACTANT
Depth (ft)	4597.00	1303.00	3150.00
Gravity (°)	33.00	14.3	37.00
Viscosity (cp)	1.2	3215.00	6.5
Original Oil-in-Place	92876.00	421418.00	85059.00
Net Pay (ft)	47.00	118.00	23.00
Porosity (fract)	0.3	0.318	0.16
Initial Oil Saturation (fract)	0.90	0.608	0.625
Initial Oil Formation Volume Factor (fract)	1.06	1.05	1.18
Temperature (°F)	149.00	98.00	77.00
Pressure (psi)	3836.00	--	--
Permeability (md)	500.00	1375.00	108.00
Average Residual Oil Saturation (fract)	--	0.518	0.401
Swept Zone Oil Saturation (fract)	0.44	0.385	0.385
Sweep Efficiency (fract)	--	0.518	0.933
Initial Water Saturation (fract)	0.10	0.392	0.38
Current Formation Volume Factor (RS/ST)	1.05	1.05	1.18
Existing Producers (%)	30.00	35.00	100.00
New Producers (%)	70.00	65.00	0.00
Existing Injectors (%)	60.00	0.00	0.00
New Injectors (%)	20.00	100.00	100.00
Workovers (fract)	0.25	0.23	1.00
Typical Spacing (Wells/Acre)	40.0	2.5	5.0
Half-typical Spacing (Wells/Acre)	20.0	1.25	2.5

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1985

TUESDAY, MARCH 20, 1984

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:10 p.m., in room SD-366, Dirksen Office Building, Hon. Pete V. Domenici, presiding.

Also present: Paul Gilman, professional staff member; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator DOMENICI. We are going to conduct this hearing in two parts. Assistant Secretary of Energy Research of the U.S. Department of Energy, Dr. Alvin W. Trivelpiece will lead off and then we will have public witnesses who will follow him as a panel. Let us proceed. Let me make a very brief opening statement.

This is to review the fiscal year 1985 budget request for the Department and those programs administered by the Office of Energy Research. Mr. Secretary, we hope you will testify on behalf of the administration and explain their particular requests and then we will have outside witnesses, as I indicated, give us their observations and thoughts.

I would like to make a brief statement and observation regarding the status of the budget policy. There is probably some concern here in the Senate, because much is being said about feezing the budget authority for the domestic accounts for a year, whether it is under that budget that has been announced by the Republican leadership and the President or others who have budget ideas to freeze for 1 year seems to be rather contagious.

We are talking about a freezed budget authority at the appropriated levels but nobody is making the decision for the appropriators as to the individual accounts that are being spoken of, in the sense that the entire combination of accounts would be constituted by budget authority. So these programs which you are talking about, which this particular Senator is very interested in, clearly can be accommodated but it will be up to the appropriators to make some necessary reductions elsewhere.

I think that will happen. I thought it would be good to put it on the record the way I understand it. There are some specifics that I would like to make a part of the statement and a part of the record. I will ask Senator Ford if he has any opening remarks.

STATEMENT OF HON. WENDELL H. FORD, A U.S. SENATOR FROM THE STATE KENTUCKY

Senator **Ford**. Mr. Chairman, I think your statement describes several planned next generation facilities for high nuclear physics, fusion, research and material research. Before we become too committed to these facilities there should be some indication as to what their total cost is going to be and for each facility we need that information and the total estimated cost. The uncertainty of this bothers me a little bit.

The portion of fiscal years 1985, 1986, and 1987 on into 1989 we are beginning to get factored in and we will be devoted to the projects. I will see what I can do about asking some questions of the Secretary to get into that as we move along. I want to start comparing the progress in some as it relates to no progress in others.

I appreciate the opportunity to be here today and I appreciate the Secretary's coming. I would like to compliment the Secretary on his 72-page detailed statement.

Senator **Domenici**. We will make your statement part of the record. You may proceed as you see fit.

STATEMENT OF DR. ALVIN W. TRIVELPIECE, DIRECTOR, OFFICE OF ENERGY RESEARCH, DEPARTMENT OF ENERGY

Dr. **Trivelpiece**. Thank you, Mr. Chairman and members of the subcommittee. Before turning to some specifics of my testimony, I would like to make some general remarks. I am going to talk about the DOE's Magnetic Fusion, High Energy and Nuclear Physics, and Basic Energy Sciences and Biological and Environmental Research programs. In aggregate, these programs together with several smaller ones amount to something like $1.899 billion in the fiscal year 1985 budget.

They span an enormous range of activities from the very basic to applied research. As you know, the administration has tried to emphasize certain aspects of basic research and science and technology. In so doing, the adminstration is trying to emphasize the development of talent through support of excellent research by encouraging partnerships with the laboratories, universities and industry. In that sense, if you look back over the collection of things that have been supported in the area of basic research over the past 30 years in the United States, you find a remarkable event if you take those activities and carry them forward and try to determine, from basic activities that are now part of our marketplace, what has happened in terms of the gross national product. What fraction of our gross national product now, in terms of domestic sales and foreign sales, do you attribute back to basic research and applied research activities 10, 20, 30 years ago?

It turns out, I think, that the multiplier is a very large number. This has been just plain good business on the part of the United States. You, Mr. Chairman, and members of the committees here in the Congress operate to some extent as the board of directors for the American taxpayer. If you were operating as a company, and you asked whether or not this has been a good investment on the part of the taxpayers in terms of what is available to them for medical purposes and from commercial products you would have to say this has been just an excellent business investment from a strict business point of view.

That idea has been identified also by the heads of states that make up the economic summit. The Versailles, Williamsburg, and the forthcoming London summit have as one of their features the early statements by the heads of state that science and technology are one of the cornerstones of future economic growth and that, to some extent, we should engage in some collaborative and cooperative activities in various areas of science and technology. The Department of Energy has the responsibility in three of those areas, the Magnetic Fusion Program, the High Energy Physics Program and the breeder program.

There will be some discussions prior to the London summit, which will take place in June, on possible areas of collaboration.

Each of the programs that I have been discussing in some sense contributes to the training of talent in the United States. It does so by providing the challenge that makes the frontier available for young scientists to dedicate their efforts. These programs are also dedicated to excellence, and they are in many areas the frontier programs of science, not only in the United States, but in some cases also the world.

The degree to which they involve partnership, I think, is more than is generally noted. For instance, the facilities in the Basic Energy Science Programs which are at many of the laboratories are used in fact about a third of the time by our Nation's industries. That improves technology transfer from the laboratories to industry. This gives our Nation's industries a competitive position in many areas that they might not otherwise be capable of achieving.

These programs are also science-intensive for the most part and in some cases they involve studies of nuclear material, the interior of atoms, and so on.

Before turning to some of these other budget items, I wanted to talk about a couple of small items in the budget, the things in some sense that do not cost very much, but which I believe to be very important. For instance, DOE has no direct educational mission like the National Science Foundation does. However, we are responsible through our contracts for training in excess of 5,000 graduate students in the United States.

In addition to having a major role in the graduate education program in the United States; through some volunteer efforts, our laboratories also play a role in high school education. At the Fermi National Laboratory for the scientists volunteer their time on Saturdays to have high school students who are selected from throughout the Chicago area, come and receive training in various areas of science that the people at Fermi lab are experts in.

In the past few years, some 900 high school students have spent 10 weeks there. As a result the Aurora Foundation has donated $12,000 to Fermilab in order to continue this very good program. Obviously, if we are going to improve our ability to train talent in the United States, it is essential to begin at the high school level and earlier. This kind of volunteer effort at our laboratories is to be commended.

In addition, there is a laboratory cooperative program which, Mr. Chairman, I am sure you are familiar with. You notice this year we are asking for $3 million more for that, nearly double. That program provides an opportunity for undergraduate students in many of our Nation's universities to take advantage of the facilities at DOE national laboratories and spend summers there as well as having some opportunity for their teachers to spend some time there. We have a prep program which provides an opportunity for women and minorities interested in engineering to take advantage of the opportunities provided by summer enrichment activities and that has been quite useful also.

This year we are asking for $6 million for the University Instrumentation Program, which last year we received approval for $4 million. That program is dedicated to trying to upgrade the instrumentation at our Nation's universities to try to offset some of the deterioration that has taken place over the years and providing first class equipment available to graduate and undergraduate students.

Turning now to the programs, the fiscal year 1985 High Energy Physics Program request is $561 million. High energy physics had a rather busy year. From a physics point of view there were several discoveries, such as the W plus and minus particles and the Z particle at CERN. I think the point is that their existence confirms certain aspects of the theoretical structure of understanding of the elementary properties of matter. That information, together with some of the problems that were occurring with the Isabelle accelerator at Brookhaven, led the high energy physics advisory panel to recommend that we begin the initial work to start a new facility called the superconducting super collider which will provide 20 tera-electron volt proton collisions.

In addition this year another activity that is taking place is that the energy saver project at Fermilab has been made operational. It has already operated at 800 GeV energy, which is the world's record. In addition something like a $750,000 reduction in the electricity bill has resulted, per month, from the operation of that accelerator in this mode. We have also initiated the Stanford linear collider.

In nuclear physics, as you are aware, we hope to start a project called the continuous electron beam accelerator facility, which has been recommended by the Nuclear Science Advisory Committee. It offers some new opportunities to understand the charactertics of matter that have been heretofore impossible.

The magnetic fusion energy request in the President's fiscal year 1985 budget is $483 million. I think that reflects a strong commitment on the part of the administration even though that is slightly less than the cost-of-living increase. You are aware of the current energy climate. There does not seem to be any compelling reason to accelerate the fusion program at the moment, but I think it is also sound business to maintain the investment that has been made in it at the various laboratories. Good progress is being made. As you are aware, the goal of the fusion program is to produce fusion ignition. The device called TFTR, which is at Princeton University, has been operating this year. It is producing good results and we see no reason why it should not carry out the experiments planned for it in 1986 which should lead to a demonstration of fusion burning.

The request for Biological and Environmental Research Program, is $189 million. You are familiar with this program and its history in the Atomic Energy Commission. It has provided knowledge on radiation biology and has provided the basis for nuclear medicine activities in the United States.

The recognition of the importance of that activity, I think, is highlighted by the fact that this year the President has approved our recommendation that John Lawrence and Alex Holender receive the Fermi prize. That prize reflects the fact that one of them is the father of nuclear medicine and the other is the father of radiation biology. We plan to have a ceremony at the Department on May 9 and carry over some activities on the 10th. We certainly hope that you and the members of this committee might possibly find the time to help us honor these gentlemen.

The Basic Energy Sciences Program fiscal year 1985 request is $419 million. It is the area within the ER programs where the facilities are provided for materials research. These include nuclear reactors and synchrotron lite sources and things like that. I would like to just mention one area of an accomplishment which involves something that took place at the Oak Ridge National Laboratory and that is the development of material, which is called nickel aluminide. It has the feature that it has unusual strength at high temperature and furthermore its strength does not deteriorate as the temperature increases. Its coming into existence was the result of some of the basic material studies at Oak Ridge supported in the Basic Energy Sciences Program.

The reason I mentioned it is become it was one of the recipients of an IR 100 award. This year the Department of Energy, through its various programs, received nine IR 100 awards, which I think speaks well for the degree to which the Department is involved in things that do lead to practical technology transfer.

Mr. Chairman, I have the possibility, of course, for talking for a long time about these programs, but I think I would like now to turn to questions.

[The prepared statement of Dr. Trivelpiece follows:]

Statement of Alvin W. Trivelpiece

Director of Energy Research

Department of Energy

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to appear here today to present the FY 1985 budget request for the programs supported by the Office of Energy Research (ER). They include: High Energy and Nuclear Physics, Basic Energy Sciences, Magnetic Fusion Energy, Biological and Environmental Research, Energy Research Analyses, University Research Support, University Research Instrumentation and Multiprogram General Purpose Facilities. The High Energy and Nuclear Physics programs are under the General Science and Research appropriation. All of the other programs are under the Energy Supply R&D appropriation. The FY 1985 budget request for all ER programs is shown in Table 1.

This budget request reflects the goals and strategies set out in the Fourth National Energy Policy Plan (NEPP-IV), published in October 1983. As stated in NEPP-IV, the goal of our national energy policy is to foster an adequate supply of energy at reasonable costs. The strategies for achieving this goal are: (1) to minimize Federal control and involvement in energy markets while maintaining public health and safety and environmental quality, and (2) to promote a balanced and mixed energy resource system.

Table 1
Office of Energy Research
Summary by Program
($ in millions)
Budget Authority

	FY 1984 Estimate	FY 1985 Request
General Science & Research		
High Energy Physics	$480.0	$561.0
Nuclear Physics	159.0	183.6
General Science Program Direction	2.2	2.2
Subtotal	641.2	746.8
Energy Supply - R&D		
Basic Energy Sciences	$337.3	$419.5
Magnetic Fusion Energy	470.8	483.1
Biological & Environmental Research	183.9	189.1
Energy Research Analyses	2.9	3.0
University Research Support	5.5	9.2
University Research Instrumentation	4.0	6.0
Multiprogram General Purpose Facilities	42.1	39.0
Advisory & Oversight Program Direction	3.4	2.9
Policy and Management	1.3	0.5
Subtotal	$1,051.2	$1,152.3
Total ER	$1,692.4	$1,899.1[a/]

[a/] These estimates reflect $15.6 million for savings resulting from FY 1985 management initiatives.

NEPP-IV also stresses the need to: 1) increase our basic understanding of nature and matter, 2) advance the frontiers of scientific, and engineering knowledge that forms the basis for technological innovation, 3) assess the potential human health and environmental effects associated with development and use of energy technologies, and 4) transfer new knowledge to the private sector where it can be developed further and applied. The programs that I will discuss today accomplish all of these things. They do so through the research itself, through a variety of communications mechanisms such as publications, workshops and private sector access to laboratory facilities and, finally, through the training of graduate students who carry their knowledge of cutting-edge research into their careers after completion of their studies.

At this point I would like to discuss each of the programs mentioned above in some detail.

HIGH ENERGY AND NUCLEAR PHYSICS

The High Energy and Nuclear Physics programs contribute to DOE's implementation of NEPP-IV's goal and strategies by supporting the most basic long-term scientific research--that aimed at improving our understanding of the fundamental constituents of matter and energy and the basic forces in nature that control the interactions among those constituents. This research advances the frontiers of our scientific and technical knowledge and provides fundamental building blocks for technological innovation. Because the research is long-term and not initially applicable to any given energy technology, the private sector has no incentive to support research in high energy and nuclear physics.

The Department's High Energy and Nuclear Physics programs have long been important to the vitality and development of science and technology in the U.S. Through the efforts of its practitioners, this research has made vital contributions not only to energy resource development but to education, health, industry and national defense. Significant contributions to the economic growth and prosperity of the Nation have come directly from the results of the research, from technological spinoffs, and from the training of tomorrow's scientists through the involvement of university graduate students in carrying out the research. Through technology transfer, these ideas and people have made contributions in a variety of industries including medical instrumentation, control and instrumentation of industrial processes, and the production of nuclear energy. In FY 1985, the HENP programs will continue to increase our fundamental understanding of the physical world and assure that research results are available to those who might use them.

In this century, scientific investigation has focused on understanding the relationships among ever more fundamental constituents of matter, with the research frontier moving from atoms, to nuclei, to the constituents of nuclei (protons and neutrons) and recently to even more elemental subnuclear constituents, somewhat whimsically referred to as quarks and gluons. The Department funds approximately 90% of the High Energy and Nuclear Physics research that is carried out in the United States. The National Science Foundation supports the rest in a joint endeavor with the Department.

The High Energy and Nuclear Physics programs are closely related in terms of goals, the types of facilities and equipment used to reach these goals and the impact that research in one program has on the other. Although the two programs have related goals, they have quite different research emphases.

The Nuclear Physics program strives to attain a better understanding of the structure and properties of the atomic nuclei that comprise the cores of the atoms and the forces that govern their behavior. It also seeks to determine how the quark substructure of protons and neutrons influences the make-up and characteristics of nuclei (i.e., how do quarks act when they are imbedded in nuclei?). High Energy Physics research seeks to understand the nature and relationships among the fundamental forces of nature and to understand the ultimate structure of matter in terms of the properties and interactions of its basic constituents.

Although the focus of each of the programs is somewhat different, most experiments in both the High Energy and the Nuclear Physics programs depend on large experimental facilities that accelerate beams of particles to collide with stationary targets or other moving particle beams. These are required to probe the properties of atomic nuclei, in the case of Nuclear Physics, or to study elementary particles such as quarks in the case of High Energy Physics. The primary experimental technique used in both programs is to analyze the results of the collisions. Many entirely new forms of matter can be created in these collisions by means of a series of energy-to-matter transformations. The study of these dynamic phenomena then reveals the properties of the underlying building blocks and basic forces involved. In general, as the particles studied become more elementary, their component parts are bound together more tightly. Thus, larger, more powerful and complex accelerators, detectors and supplementary equipment are required to carry out the research.

Although progress in High Energy and Nuclear Physics is dependent on the availability of these forefront accelerator and colliding beam facilities, as well as on the sophisticated detectors that record the effects of particle collisions, these advanced facilities are only one facet of the program. Progress in both High Energy and Nuclear Physics features a continuing interplay of advancements in experiment, theory and technology. HENP experiments are done at the very forefront of theoretical and technical knowledge, and the range of experiments possible is determined by available technology. Physicists frequently have to invent unique equipment and technology to carry out the experiments of greatest importance. Great strides in technology advancement are now coming at the same time that our understanding in both fields of research is growing rapidly. Together, these advancements provide a clear view of the kinds of new experimental facilities that will be required to take advantage of the growing number of successes in recent years.

The large scientific facilities supported by the HENP programs are available to qualified scientists for experimental research on the basis of the merit of their scientific proposals. Approximately 75% of the research in High Energy Physics is done by university-based scientists who usually form collaborations with scientists from other universities or from DOE's laboratories. Typically, proposals from university and laboratory user groups for accelerator research time are evaluated by scientific program advisory committees which recommend for selection those proposals with the greatest scientific promise. The High Energy Physics program operates almost exclusively in this mode, while Nuclear Physics, in addition to national facilities, also supports dedicated accelerator facilities located on the campuses of four leading universities (Duke, Yale, Texas A&M, and the University of Washington) where research is primarily conducted by resident researchers and graduate students. To complement, interpret, and guide the experimental work, each program supports a vigorous theoretical research effort at universities and at the national laboratories.

HIGH ENERGY PHYSICS

Considerable progress has been made in recent years toward improving our understanding of energy and matter and their most elemental transformations. We have not only identified a growing number of particles, but have seen how they relate to one another and how they can be transformed during collisions with other particles in accelerator experiments. A long-standing goal of high energy physicists is to understand these diverse and complex phenomena by formulating a theory which would encompass all of the interactions of matter and energy revealed by their research. These "unified" and "grand unified" theories, as physicists call them, hypothesized over the last 10 years, imply that the diversity existing in the universe today may have evolved from a single force, or process, that existed only when the universe was formed some 20 billion years ago.

These theories aim at linking together, or unifying, the four known fundamental forces of nature and identifying the basic constituents, or building blocks, of matter. The electromagnetic force describes how atoms and molecules are formed and is the cornerstone to understanding chemistry, electronic communications and biological processes. The weak nuclear force describes processes such as the radioactive decay of nuclei. The strong nuclear force helps describe how the nucleons, and thus all nuclear matter, are held together. The gravitational force, perhaps the most familiar of the four forces of nature, explains such things as why rocks fall and planets move in their orbits. The basic constituents of matter are presently hypothesized to consist of "quarks and leptons." Quarks are thought to be the constituents of nuclear matter. Leptons are weakly interacting particles, like the electrons, muons, and neutrinos.

Recent research results have led to an increasingly better understanding of the forces of nature. That understanding is defined in theories that indicate that the weak nuclear and the electromagnetic forces are actually different forms of a single force--referred to as the electroweak force. Two U.S. physicists shared in the 1979 Nobel Prize for work on this unification. The 1980 Nobel Prize in Physics was also awarded to two U.S. physicists for work that is expected to contribute to unification theories that encompass the strong nuclear and electroweak forces.

Eventually, it is postulated that the gravitational force will be incorporated into a super unification theory, bringing all of the basic forces into a unified framework.

Among the predictions of the new theories is that protons, which were previously thought to be absolutely stable, do eventually decay; and that neutrinos, among the most abundant particles in the universe and previously thought to be massless, could instead have a small mass. Special emphasis in the experimental program is focused on testing these and other predictions of the unified theories.

Advances in experimental research during 1983 were highlighted by the observation at CERN in Geneva, Switzerland of the long-sought particles (called "W" and "Z") which are the carriers of the weak nuclear force. The discovery was made by an international team of researchers which included research scientists from the U.S. The observation of these particles, each of which is almost a hundred times heavier than a proton, was critical to the theory of unification of the weak and electromagnetic forces which had predicted their existence. Significant progress has also been achieved in precision measurements of the results of collisions of high energy electrons and positrons at the Positron-Electron Project (PEP) and the Stanford Positron-Electron Asymmetric Ring

(SPEAR) facilities at the Stanford Linear Accelerator Center. Teams of university and laboratory scientists have measured a surprisingly long lifetime of a particle thought to contain one of the heaviest quarks, and have observed the presence of new states of matter resulting from decays of particles containing "charmed" quarks. The long lifetime, interesting in itself, has also given new clues in the search for even heavier particles. One interpretation for the new states observed is that they could be made up entirely of the gluons that are thought to be the carriers of the strong nuclear force.

The experimental work in High Energy Physics is carried out primarily on the high energy accelerator and colliding beam facilities operated by the Department. In FY 1985, these include: the 30 GeV (billion electron volts) proton synchrotron, called the Alternating Gradient Synchrotron (AGS), at Brookhaven National Laboratory (BNL); the 1000 GeV superconducting magnet proton synchrotron at Fermi National Accelerator Laboratory (Fermilab); and the 32 GeV linear electron accelerator at the Stanford Linear Accelerator Center (SLAC). SLAC also has two electron-positron colliding beam facilities for which the linear accelerator acts as the injector: the Stanford Positron Electron Asymmetric Ring (SPEAR) (4 GeV x 4 GeV) and the Positron-Electron Project (PEP) (15 GeV x 15 GeV). Each of these DOE accelerator centers provides a unique set of experimental capabilities, complementary to the others. As an ensemble they provide capabilities essential for a comprehensive forefront national research program in high energy physics. A major part of High Energy Physics funding is required to develop, maintain and operate the major accelerator and detector facilities at these laboratories.

Before I discuss the budget request, I would like to report a major technological achievement during this last year. The Energy Saver, the world's first high energy accelerator using superconducting magnets, has been brought into successful operation at Fermilab. The last superconducting magnet was installed in March 1983 and by early July the beam had been accelerated to 512 GeV, a world record energy. The accelerator is presently providing beam to experiments at 400 GeV. This energy will be increased to approximately 700 GeV in the near future. In FY 1985 the accelerator is expected to operate at energies near 1000 GeV. This is truly a major step in the development of superconducting magnet technology.

FY 1985 HIGH ENERGY PHYSICS BUDGET REQUEST

The FY 1985 request for the High Energy Physics program is $561.0 million, which consists of $381.6 million for Operating Expenses, $65.4 million for Capital Equipment and $114.0 million for Construction (Table 2).

Table 2
High Energy Physics
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Operating Expenses		
Physics Research	$ 99.5	$107.7
Facility Operations	161.0	182.1
High Energy Technology	82.0	91.8
	$342.5	$381.6
Capital Equipment	51.5	65.4
Construction	86.0	114.0
Total High Energy Physics	$480.0	$561.0

The FY 1985 request for Operating Expenses will permit an overall utilization level of the High Energy Physics accelerator facilities at about 55%, somewhat above the FY 1984 level. The request also provides continuing support for university and laboratory based research groups including accelerator experiments, non-accelerator experiments, and theoretical research. There will be continuing accelerator R&D activities at Fermilab and SLAC in support of ongoing construction projects.

The FY 1985 request for Operating Expenses also will provide for preliminary R&D studies for the next generation particle accelerator designated the Superconducting Super Collider (SSC). Construction of such a new facility was recommended by the High Energy Physics Advisory Panel (HEPAP). Specifically, HEPAP recommended as highest priority "the immediate initiation of a multi-TeV high luminosity proton-proton collider project with the goal of physics experiments at the earliest possible date." The SSC would provide a research capability in an unexplored domain for which there are no existing or planned facilities anywhere in the world and in which there is strong expectation of major research breakthroughs.

The Department has evaluated the HEPAP recommendation and decided to initiate an R&D program at various locations in FY 1984 to investigate key issues associated with construction of such an accelerator. The major emphasis in FY 1984 is on superconducting magnet R&D and on developing a reference design with a cost estimate based on credible assumptions about possible achievements in the R&D program. In FY 1985, preliminary R&D for the SSC will focus on development and evaluation of technical options for magnets and other accelerator components, development and validation of cost saving designs and fabrication techniques, consideration of accelerator design alternatives and trade-offs, and cost optimization studies.

The FY 1985 Capital Equipment request of $65.4 million provides a substantial increase above the FY 1984 level in order to meet some of the major needs associated with implementation of research programs using the major new research capabilities being provided by the Tevatron I and Tevatron II projects at Fermilab and the Stanford Linear Collider (SLC) at the Stanford Linear Accelerator Center. This increase in Capital Equipment funding in FY 1985 is essential for the effective utilization of the U.S. High Energy Physics facilities and for the health of the U.S. High Energy Physics program for the remainder of the 1980's.

The request for Capital Equipment gives priority to Fermilab for the new secondary beam lines and detector systems needed to implement the 1000 GeV research program associated with the Tevatron II fixed target program and for work on detectors needed for the Tevatron I proton-antiproton colliding beam research program. Priority is also given to SLAC for work on detectors for electron-positron colliding beam research at the SLC; to the university program to meet the needs of experiments at the U.S. laboratories and at the Large Electron Positron (LEP) facility at the CERN Laboratory in Geneva, Switzerland; and for non-accelerator experiments.

In addition to programmatic equipment needs, the High Energy Physics program provides for the general purpose equipment requirements for all DOE programs at the Brookhaven National Laboratory.

A total of $114.0 million in Construction funding for High Energy Physics projects is requested in FY 1985. The projects are listed in Table 3. A major portion of this request is for continued construction of the Stanford Linear Collider ($60.5 million). The primary goal of this project is to develop and demonstrate the technical feasibility of using linear accelerators with precisely controlled, high intensity and highly focused beam pulses to provide high rates of electron-positron collisions at energies far beyond those that will be affordable for circular colliders. SLC also will give U.S. physicists early access to the important physics which can be studied with copious production of the Z^0 particle.

Table 3
High Energy Physics
Budget Authority
($ in millions)

Construction	Prior Years	FY 1985 Request	TEC	Completion Date
Tevatron I (81-E-218)	$ 54.1	$ 21.3	$ 82.5	FY 1986
Tevatron II (82-E-206)	37.8[a]	12.0	49.0	FY 1985
Stanford Linear Collider (84-ER-133)	34.3[b]	60.5	112.0	FY 1986
Accelerator Improvement Project (85-R-100)	N/A	10.0	N/A	FY 1987
General Plant Projects (85-R-101)	N/A	10.2	N/A	FY 1987
Total Construction		$114.0		

a/ Includes $0.8 million for PE&D
b/ Includes $2.3 million for PE&D

The request also provides for completion of the Tevatron II project at Fermilab ($12.0 million) and continuation of Tevatron I ($21.3 million) at Fermilab.

Funds are requested for Accelerator Improvement Projects ($10.0 million), which are critical on an annual basis to maintain the scientific effectiveness and the operating reliability and efficiency of the accelerator and colliding beam facilities. The request also provides for an improved level of General Plant Projects ($10.2 million). Within the GPP request, emphasis is placed on the needs at BNL, since the High Energy Physics program provides funding for the general purpose needs of all DOE programs at this laboratory.

NUCLEAR PHYSICS

Nuclear knowledge, techniques, instruments, and applications pervade American society. These serve as the basis for our national defense strategy, for therapeutic and diagnostic medical applications, for the generation of electricity with nuclear reactors (fission now and fusion in the future), and for a large and diverse array of applications in industry. The behavior of nuclei and nuclear matter determine the physical properties of our universe--from its creation from a primordial "soup" of energy and elementary particles, to the reactions which power our sun, to the makeup of our planet. Thus, basic nuclear research is both a central component in our Nation's long-term investment in its technological future and an essential foundation to any basic understanding of the world about us.

The Nuclear Physics program is a comprehensive program of interdependent experimental and theoretical investigations of atomic nuclei. The goal of the program is to understand the interactions, properties, and structures of atomic nuclei and nuclear matter at an elementary level and to gain knowledge of the fundamental forces of nature by using nuclei as a proving ground.

Experimental and theoretical investigations are leading nuclear scientists to conclude that a new level of understanding of atomic nuclei is achievable. This optimism arises from evidence that: (1) the mesons, protons, and neutrons which are inside nuclei are themselves composed of quarks and gluons and (2) the theory called quantum chromodynamics (QCD) can be developed into a theory which both describes correctly the interaction between quarks and gluons and is also an exact theory of the strong nuclear force. These concepts will be important drivers of basic nuclear research and will determine facility needs in FY 1985 and years beyond.

As is the case with High Energy Physics, the Nuclear Physics program depends upon the operation of large and complicated accelerator facilities which provide a variety of projectile beams required for forefront nuclear research. Seven existing accelerator facilities are operated by the Nuclear Physics program as national facilities whose beam time is made available to all the Nation's scientists on the basis of the scientific merit and technical feasibility of proposed research projects. The national facilities are: the Clinton P. Anderson Meson Physics Facility (LAMPF) at Los Alamos National Laboratory (LANL); the Bates Linear Accelerator Center at the Massachusetts Institute of Technology (MIT); the SuperHILAC/Bevalac at Lawrence Berkeley Laboratory (LBL); the Holifield Heavy Ion Research Facility at Oak Ridge National Laboratory (ORNL); the 88-inch Cyclotron at LBL; the Tandem/Linac Facility at Argonne National Laboratory (ANL); and the Double MP Tandem Van de Graaff facility at Brookhaven National Laboratory (BNL).

Long range planning for the needs of nuclear physics research is performed in concert with the National Science Foundation (NSF), which has a smaller, complementary program in this area, and with input from external and internal reviews of specific research areas and from the scientific community itself. In cooperation with the Department of Energy and NSF, the Nuclear Science Advisory Committee (NSAC) has developed a long-range plan for basic nuclear research in the United States -- "A Long Range Plan for Nuclear Science" (December 1983). This long-range plan is based upon a comprehensive review of scientific advances and opportunities which have emerged since development of the previous long-range plan dated December 1979.

The 1983 Long Range Plan reaffirms NSAC's April 1983 recommendation that construction of a 4 GeV, continuous electron beam facility should be initiated as soon as possible, and it identifies a longer term, high priority need for a relativistic heavy ion collider facility. From very different aspects, both the electron facility and the heavy ion collider share the common scientific goals of understanding quantum chromodynamics as an exact theory of the strong nuclear force and understanding the ways in which the quarks inside protons and neutrons determine the behavior and makeup of nuclei. Also, in the interaction of very energetic colliding beams of nuclei, extreme conditions of energy density will occur, conditions which previously existed only in the early instants of creation of the universe. The energy densities will be so great that transitions to new phases of nuclear matter seem likely. If these bright prospects can be realized, a new level of knowledge of atomic nuclei will be achieved. In accord with the Long Range Plan, the FY 1985 construction request provides for initiation of construction of a 4 GeV, continuous electron beam facility at Newport News, Virginia and for a significant advancement in our capability for heavy ion nuclear research at Brookhaven National Laboratory.

FY 1985 NUCLEAR PHYSICS BUDGET REQUEST

The FY 1985 request for the total Nuclear Physics program is $183.6 million, which consists of $144.6 million for Operating Expenses, $13.7 million for Capital Equipment and $25.3 million for Construction (Table 4).

Of the Operating Expenses request of $144.6 million, $73.7 million is needed for operation of the existing national and dedicated accelerator facilities to maintain the overall utilization of the national accelerator facilities at 90% of the FY 1984 utilization levels. An additional $1.1 million is required for operation of the new SLAC injector discussed later in my testimony.

The FY 1985 Operating Expense request will allow emphasis to be given to exploitation of new research capabilities provided by successful completion of construction projects in FY 1984 and FY 1985. These include: (1) the Argonne Tandem/Linac Accelerator System (ATLAS) to provide heavy ion beams to investigate how colliding nuclei exchange mass, energy, and spin; (2) the Bates Electron Accelerator recirculator project (MIT) which provides electron beams for precision electron-nuclear scattering studies at higher energies than previously available; and (3) a new injector at SLAC to provide high energy, precisely pulsed electron beams to examine the magnetic properties of nuclei and for exploratory

Table 4
Nuclear Physics
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Operating Expenses		
Medium Energy Nuclear Physics	$ 65.0[a]	$ 72.0
Heavy Ion Nuclear Physics	47.0	49.8
Low Energy Nuclear Physics	13.0	13.5
Nuclear Theory	9.0	9.3
	$134.0	$144.6
Capital Equipment	11.3	13.7
Construction	13.7[b]	25.3
Total Nuclear Physics	$159.0	$183.6

[a] Includes $3.0 million which was provided under Defense Programs for LAMPF facility operations.

[b] Does not include $5.0 million proposed reprogramming from the HEP ISABELLE project to the Tandem/AGS Heavy IonTransfer Line project.

experiments into the ways in which quarks influence the makeup and behavior of nuclei. In the FY 1985 Operating Expenses request, $60.5 million is planned for experimental research and $9.3 million for theoretical research.

Of the total FY 1985 Operating Expenses request, 26% is planned as direct support to universities, consisting of off-campus experimental research; operation of Bates and the four dedicated on-campus accelerator facilities; research at on-campus facilities; research and development on the 4 GeV, continuous electron beam facility by the Southeastern Universities Research Association; and theoretical research. Additional university support in an amount almost equal to the direct support is provided through the accelerator centers to support experimental research and operate the accelerators.

As the various Nuclear Physics research programs move into new scientific areas, there is a continuing need to develop new detection instrumentation, upgrade the capabilities of existing instruments, improve the efficiency and sophistication of data acquisition and analysis systems, and improve the performance and beam characteristics at the major Nuclear Physics accelerator facilities. In general, the more complex and precise experiments require the development of entirely new techniques.

The increasing complexity of Nuclear Physics experiments requires larger and more powerful data acquisition and analysis systems. The FY 1985 Capital Equipment request for Nuclear Physics is $13.7 million. This request includes equipment to be used in the first heavy ion experiments at the Alternating Gradient Synchrotron (AGS) at the Brookhaven National Laboratory. At the Lawrence Berkeley Laboratory, the start of fabrication of a major new instrument, the Dilepton Spectrometer, is planned for FY 1985. This instrument will allow researchers to investigate new states of nuclear matter created in very high energy collisions between nuclei. Capital Equipment funds also are needed to exploit the capabilities of the Holifield Heavy Ion Research Facility at Oak Ridge National Laboratory and the new Argonne Tandem/Linac Accelerator System (ATLAS) at the Argonne National Laboratory. At the Bates Linear Accelerator Facility at MIT the upgrade of a beam line which feeds three magnetic spectrometers will provide new research capabilities and increased efficiency.

In addition to programmatic equipment needs, the Nuclear Physics program provides for the general purpose equipment requirements for all DOE programs at the Lawrence Berkeley Laboratory.

A total of $25.3 million in Construction funding for Nuclear Physics projects is requested in FY 1985. These projects are listed in Table 5. A major feature of the FY 1985 Nuclear Physics

Table 5
Nuclear Physics
Budget Authority
($ in millions)

Construction	Prior Years	FY 1985 Request	TEC	Completion Date
Univ. Accelerator Upgrade (84-ER-110)	$8.0	$ 11.0	$ 19.0	FY 1987
Tandem/AGS Heavy Ion Transfer line (84-R-123)	$5.0a/	5.3	10.3	FY 1986
Accelerator Improvements Projects (85-R-200)	N/A	3.5	N/A	FY 1987
General Plant Projects (85-R-201)	N/A	3.5	N/A	FY 1987
Continuous Electron Beam Accelerator Facility (85-R-203)	0	2.0	b/	b/
Total Construction		$25.3		

a/ Proposed reprogramming from ISABELLE construction project (78-10-6)
b/ The total estimated cost and exact construction dates are under review. The FY 1985 request provides for architect-engineering work, detailed design, and preliminary site work.

program is the initiation of construction of the Continuous Electron Beam Accelerator Facility project (CEBAF) at Newport News, Virginia. This will be a major facility employing an electron linear accelerator complex capable of delivering intense, continuous electron beams in the energy range from 500 million to 4 billion electron volts. The intensity (number of particles per second) of the beam in combination with multi-GeV energy and uniquely high duty factor (continuous rather than pulsed beam) will make this facility unmatched in the world. The CEBAF will have the capability of investigating a crucial class of problems facing nuclear physics today, namely, understanding the relationship between the traditional and emerging descriptions of nuclear dynamics. The aim is to synthesize the traditional picture and the emerging view of an underlying structure of quarks and gluons into a unified description.

In FY 1985, $2.0 million in Construction funds will be used for architectural and engineering services, for minor site work, and for design beyond the conceptual level in order to establish a reliable cost estimate for the CEBAF project.

The Nuclear Physics Construction budget also requests funds for the ongoing construction of the University Accelerator Upgrade Project at the University of Washington and Yale University ($11.0 million) and for the Tandem/AGS Heavy Ion Transfer Line project at

Brookhaven National Laboratory ($5.3 million). The FY 1985 request completes funding for these construction projects. The University Accelerator Upgrade Project at the University of Washington and Yale University will maintain the forefront nuclear research capabilities of two of America's leading universities.

The objective of the Brookhaven project is to transport beams of nuclei as massive as sulfur (32 atomic mass units) from the existing Double MP Tandem Facility to the Alternating Gradient Synchrotron (AGS) for acceleration to energies of 15 billion electron volts per atomic mass unit. This project will provide an exciting new capability for research in heavy ion collisions in a new higher energy region, and is an excellent complement to Bevalac's existing lower energy (1 to 2 billion electron volts per atomic mass unit) but much higher mass (up to uranium at 238 atomic mass units) beams. Research at the Bevalac shows that concentrations of mass and energy do occur in energetic collisions of massive nuclei. Tandem/AGS Heavy Ion Transfer Line beams will extend our capabilities into regions in which the quarks inside nuclei will be violently forced together, possibly producing a transition of nuclear matter into new forms.

The request also provides $3.5 million for Accelerator Improvement Projects (AIP) at Nuclear Physics facilities taking into account the needs of the recently completed facilities now being operated, and $3.5 million for an improved level of General Plant Projects (GPP) with particular emphasis on the needs at LBL, where this program provides funding for the general purpose needs of all DOE-sponsored programs.

GENERAL SCIENCE PROGRAM DIRECTION

The FY 1985 budget request for General Science Program Direction is $2.2 million. These funds are required to provide for the salaries, benefits, travel and other expenses associated with 35 full-time equivalents in the Office of the Associate Director for High Energy and Nuclear Physics and associated support staff required to administer these programs.

Now let me turn to the Basic Energy Sciences program.

BASIC ENERGY SCIENCES

Over the years the United States has developed a tradition of leadership in science and technology which has made us a model for developing nations throughout the world. All of our national goals -- better health and quality of life for all our people, vigorous economic growth, energy self-sufficiency, national security, space exploration, etc. -- involve technological advances that depend on basic research. The principal product of this research is knowledge, the foundation from which new ideas and concepts emerge and on which important decisions can be made.

The goal of the Basic Energy Sciences (BES) program is the production of scientific and engineering knowledge for use by the Government and the private sector in developing new concepts, materials and processes for use in energy exploration, production, and conversion. The knowledge that results from BES-sponsored research, thus, becomes a vital part of the body of information on which developments in the applied energy technologies rest. Basic Energy Sciences' research in the physical, biological and mathematical sciences is carried out largely by scientists at universities and national laboratories. An important benefit that results from supporting research at universities is the technology transfer that occurs when graduate students carry their knowledge of cutting edge research to their new employment environment after completion of their studies. In addition to universities and laboratories, BES also maintains ties with industry. Industry representatives participate in workshops and in reviewing research proposals, and in membership on advisory panels to the laboratories. They also use the specialized research facilities supported by BES. Through these and other mechanisms, the results of BES-sponsored research are continually made available to industry and the academic community.

Although the pursuit of research to broaden the technology base needed for identified energy technology options is important, even more important is the need for basic research unfettered by preconceived notions of which technologies will be important several decades from now, so that new, currently unidentified options may emerge. The following examples of research results in FY 1983-1984 that have enhanced energy alternatives or improved our understanding of energy-related phenomena are illustrative of the benefits to be gained from research in the basic energy sciences.

These accomplishments include:

o The preparation of simple, low-cost, yet very high efficiency solar cells from single crystal silicon. This method involves the novel application of two new technologies: ion implantation using a relatively inexpensive glow discharge source, and pulsed laser annealing.

o The development of a new thin film photoelectrode that can convert visible light to electricity or, in the photo-assisted electrolysis of water, can generate hydrogen. Many advances reported in photoelectrochemical energy conversion in the past two years have depended on ultraviolet light; this electrode can make use of the more abundant visible spectrum of the sun.

- The demonstration that the structure and surface hardness of ceramics can be modified and controlled by means of ion implantation to produce surface hardnesses that are greater or less than that of the original ceramic. The new technology involved gives us the ability to systematically alter the structure and properties of ceramic surfaces.

- The determination, based on research carried out under the Geosciences subprogram, that two recent volcanic eruptions, Mt. St. Helens in 1980 and El Chichon in 1982, have had and will have very different effects on climate. The effects of these eruptions have been sorted out through measurements of solar radiation reaching the earth during the past few years. The differences result from differing behavior of sulfur dioxide released by the eruptions in the formation of aerosol particles in the stratosphere.

- The measurement for the first time of fusion reaction rates using subatomic particles called mesons as reaction catalysts. The resulting reaction yield of neutrons is high and the application of the concept to provide high intensity neutron sources is possible.

o Progress in genetic engineering that makes it possible to transfer pieces of DNA carrying specific genes into host plants without causing the development of tumors in those plants, which brings closer the time when it should be possible to introduce desirable traits into plants to improve the species and, thus, the production of biomass which ultimately could be converted to energy.

Improvements in existing energy technologies and the development of new energy technologies invariably come from the application of just such new scientific knowledge. Given increasing international competition in science and technology, the need for a strengthened national basic research effort is clear. External blue ribbon advisory groups have repeatedly recommended that DOE increase its funding of basic energy research and have called for the Basic Energy Sciences program to be given a larger role in developing the needed technology base for the different energy supply and conservation options. Our FY 1985 budget request for Basic Energy Sciences is consistent with these recommendations.

An important aspect of Basic Energy Sciences research activities is the support of a number of national user research facilities. Recently, several facilities were brought on-line and each promises to open whole new areas of research possibilities. These facilities include: the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory; the Intense Pulsed Neutron Source (IPNS) at Argonne; the 1.5 MeV High Voltage Electron Microscope and the Atomic Resolution Microscope, located at Lawrence Berkeley Laboratory's National Center for Electron Microscopy; and the Combustion Research Facility (CRF) at Sandia Livermore. These facilities recently brought on-line together with existing ones (e.g., the Stanford Synchrotron Laboratory), require significant increases in funding for their effective operation to assure their availability to meet the wide demand for experimental time by the research community. A complete list of BES user facilities is contained in Table 6. The Basic Energy Sciences program also is undertaking a new effort to provide needed access to supercomputers for ER-supported researchers. I will discuss that effort later in my testimony.

FY 1985 BUDGET REQUEST

The FY 1985 BES budget was developed to focus on two principal objectives. The first is to maintain a strong core program -- this involves equipping, supporting and encouraging the scientists involved in our current program activities, and training new, younger scientists, to expand the forefront of knowledge in areas likely to be important to future energy technologies. The second objective is to provide for the operation of existing, unique facilities important to research in the U.S. while, at the same

Table 6
Basic Energy Sciences Facilities

High Flux Beam Reactor (HFBR) - Brookhaven National Laboratory

National Synchrotron Light Source (NSLS) - Brookhaven National Laboratory

Intense Pulsed Neutron Source (IPNS) - Argonne National Laboratory

High Voltage Electron Microscope-Tandem Facility - Argonne National Laboratory

Oak Ridge Electron Linear Accelerator (ORELA) - Oak Ridge National Laboratory

High Flux Isotope Reactor (HFIR) - Oak Ridge National Laboratory

Combustion Research Facility (CRF) - Sandia National Laboratories, Livermore

National Center for Electron Microscopy - Lawrence Berkeley National Laboratory

Stanford Synchrotron Radiation Laboratory (SSRL) - Stanford University

Spallation Neutron Research Facility (SNR) - Los Alamos National Laboratory time, developing and constructing and providing for the future operation of needed new facilities. Additionally, in selected subprograms, opportunities for exploiting new, emerging areas, that have been identified as having great potential importance to energy, will be pursued.

The FY 1985 request for the BES program is $419.5 million. This budget which is composed of $348.3 million in Operating Expenses, $31.1 million in Capital Equipment and $40.1 million in Construction funds, maintains the needed continuity of the FY 1984 program (Table 7).

The total Operating Expenses request for FY 1985 is $348.3 million, an increase of 18% over the corresponding FY 1984 level. Most of this increase is for cost of living increases for each BES subprogram, and to meet increasing costs of facility operations. A table (Table 8) has been attached which summarizes all of the increases for FY 1985.

Of the total BES request for Operating Expenses for FY 1985, almost 40% will be spent to operate or carry out research at the major BES facilities. These are used not only by the Department, but also by

Table 7
Basic Energy Sciences
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Operating Expenses		
Materials Sciences	$125.1	$141.5
Chemical Sciences	75.5	80.9
Nuclear Sciences	37.9	49.8
Applied Mathematical Sciences	14.6	28.2
Engineering and Geosciences	19.0	20.8
Advanced Energy Projects	9.1	10.8
Biological Energy Research	10.6	12.5
Program Direction	4.0	3.8
Subtotal	$295.8	$348.3
Capital Equipment	24.3	31.1
Construction	17.2	40.1
Total Basic Energy Sciences	$337.3	$419.5

Table 8
Basic Energy Sciences
Explanation of Budget Changes from FY 1984 to FY 1985
($ in millions)

1984 Appropriation enacted $337.3

Operating Changes

Programmatic increases (described in detail below)

Materials Sciences . . . . +16.4

- Provides for increased funds for facility operations, reactor fuel element requirements and additional requirements associated with the advanced materials research initiative.

Chemical Sciences . . . . +5.4

- Provides increases for meeting facility commitments and reflects internal adjustments required to meet ongoing research commitments.

Nuclear Sciences . . . . +11.8

- Provides increases to meet commitments for the National Nuclear Data Program, an expansion to the Heavy Ion Fusion Program, and to meet facility commitments.

Applied Mathematical Sciences . . . . +13.6

- Provides increases for a significant expansion in basic research in scientific computing at national laboratories, universities and private research institutions. In addition, experimental computing capabilities are being established to support the exploration of new concepts in large scale scientific computing. Also, increase is provided for expanding access for Energy Research scientists to state-of-the-art computing capability.

Other Operating Changes	+5.3
o Provides increases in Engineering and Geosciences, Advanced Energy Projects, Biological Energy Research, and Program Direction necessary for expansion of those research activities holding the greatest promise.	
Subtotal Operating Changes	52.5
Capital Equipment Changes	
o Programmatic increase in each of the subprograms will be provided to meet facility requirements, to support the recently assigned responsibility for General Purpose Equipment at Argonne National Laboratory, and to support new requirements in areas of increasing research.	+6.8
Subtotal Capital Equipment Changes	6.8
Construction Changes	
o Programmatic increases for General Plant Projects (Argonne National Laboratory, Ames Laboratory, Notre Dame University, and Stanford University); Accelerator Improvement Projects; Kansas State Univeristy Ion Collision Physics Facility; National Synchrotron Light Source; Center for Advanced Materials and Stanford Synchrotron Radiation Laboratory Enhancement.	+22.9
Subtotal	22.9
1985 budget request	$419.5*

*The FY 1985 budget request reflects $3.0 million for savings resulting from management initiatives related to administrative processes.

other Federal agencies, by industry and by university researchers. These facilities represent a national resource that is essential for a sound national research program. The budget request will ensure continued operation and access to these facilities in FY 1985. Equally important, we have provided additional funds in FY 1985 to operate the new state-of-the-art facilities that are only now becoming fully operational and that I mentioned earlier in my testimony.

The FY 1985 budget increase will also support promising new research that we believe will have a significant impact on energy. Two items in the request exemplify research areas with great potential. These are the materials sciences research initiative, which was started in 1984, and the budget request for the Applied Mathematical Sciences subprogram. Let me first discuss the materials initiative.

The United States' economic health and national security require the maintenance of a commanding lead in high technology and reduced vulnerability to critical and strategic imported materials. In response to this challenge, an advanced materials research initiative was first proposed in FY 1984. The current budget initiative consists of a Center for Advanced Materials (CAM) at

Lawrence Berkeley Laboratory (LBL), improvements at the Stanford Synchrotron Radiation Laboratory and an expansion of actfvities at the National Synchrotron Light Source at the Brookhaven National Laboratory.

Planned activities in FY 1984 and the FY 1985 budget request are consistent with the recommendations of an ad hoc panel composed of leaders from industry, academia and the national laboratories. This panel was established in April 1983 to review the initial proposal for a center for advanced materials. Those recommendations were to continue the initiative, but to decouple the synchrotron radiation facilities from the advanced materials research and treat them separately. The panel made a number of constructive recommendations which have been factored into this year's request. A new National Academy of Sciences study of the requirements for additional major facilities currently is underway. Decisions to proceed further with construction of major new facilities will await the results of that study.

The ongoing advanced materials research activity is being organized to provide maximum benefit to the Nation. Industry will participate in the design of the CAM program to assure that the research addresses America's high-technology needs. For example an advisory board composed of scientific leaders from industry, universities, and Federal laboratories will advise the Director of LBL, home of the proposed Center for Advanced Materials, on the scientific program directions for CAM. An Industrial Fellows program has been established to provide joint LBL-industrial participation in basic research studies of mutual interest to LBL and the scientists' parent companies. An initial workshop on general concerns regarding industrial participation was held in 1983 where issues and follow-on activities were agreed upon. Four CAM workshops for the initial research areas have been held with strong industry participation.

The second expanded research activity I would like to highlight is in our Applied Mathematical Sciences subprogram for which we have requested $29.7 million in FY 1985. Supercomputers are playing an increasingly important role in many of the Department of Energy's programs. Every generation of large scientific computers has had a significant positive impact on the ability of the DOE laboratories to meet their mission goals. Each new machine has improved the laboratories' abilities to more accurately model complex physical phenomena, thus improving their productive capability and reducing the number of expensive tests now required.

Evidence of this improved capability has already been seen in the design and testing of nuclear weapons and more recently in magnetic fusion research. As they have become available, DOE programs in fundamental physical sciences are just beginning to use supercomputers as "experimental" devices for theoretical calculations. The need for large scale scientific computers is emerging in high energy physics, condensed matter research, and chemical and biological theory. Calculations of subatomic particle confinement, critical phenomena in alloy solidification and superconductors, thermophysical properties of chemical mixtures, and properties of long-chain polymers are providing insight into the basic properties of matter.

The Applied Mathematical Sciences subprogram consists of two activities. The first (Supercomputing Research) is aimed at funding research in mathematical and computational sciences that is critical to the use and development of future supercomputer systems. The second activity (Energy Science Advanced Computation) will provide network access to large-scale scientific computing required by several Departmental programs and to the basic research activities funded by the Office of Energy Research in universities, national laboratories and industry.

The goal of the Supercomputing Research activity is to advance our understanding of the fundamental concepts of mathematics, statistics, and computer science underlying complex mathematical models of the key physical processes in energy systems. Much of the scientific research and development effort throughout DOE programs is focused directly on analytical and numerical modeling of these physical processes. Basic research in the relationships among the mathematical formulation of scientific and engineering problems, the creation of algorithms for solving these problems and the architectures of parallel computers designed to implement these algorithms makes a significant contribution to the development of future energy systems.

The Energy Science Advanced Computation activity is aimed at meeting the immediate needs for supercomputer access by the Department of Energy's High Energy and Nuclear Physics, Biological and Environmental Research, and Basic Energy Sciences programs. The substantial contribution to solving the national problem of providing access to supercomputers for energy researchers will help to ensure that the U.S. maintains its lead in computational sciences related to supercomputer technology.

CAPITAL EQUIPMENT

The Capital Equipment request for FY 1985 is $31.1 million, an increase of $6.8 million over FY 1984. This level of funding is necessary to meet ongoing research requirements, additional commitments associated with the newer facilities, and additional equipment for those selected areas of promising research. Examples of equipment to be purchased include an analytical electron microscope at Los Alamos National Laboratory, neutron scattering equipment, synchrotron radiation equipment and electron microscopy equipment. Two significant items in our request for FY 1985 deserve special note. The first, is a $1.5 million request for peripheral computer equipment which is an integral part of the Applied Mathematical Sciences expanded effort. Secondly, the BES request includes $2.0 million for the General Purpose Equipment needs at the Argonne National Laboratory site. Beginning in FY 1985, this responsibility has been transferred to BES from the Office of the Assistant Secretary for Nuclear Energy.

CONSTRUCTION

Table 9 details the Construction request for FY 1985. Three of the projects are associated with our materials initiative. Another new project will provide an expanded atomic physics capability through the construction of an ion collision physics facility. In conjunction with existing capabilities, this facility will allow researchers to study the atomic physics of a range of ions at energies unmatched in the world. The project will be located at Kansas State University and will be jointly funded by DOE and the University, with the University providing the conventional construction necessary to house the new facility. The remaining construction funds are requested for General Plant Projects (GPP)

Table 9
Basic Energy Sciences
Budget Authority
($ in millions)

Construction

	Prior Years	FY 1985 Request	TEC	Completion Date
Accelerator Improvement Projects (85-ER-401)	$ 1.3	$ 2.4	$ 2.4	FY 1986
General Plant Projects (85-ER-400)	.4	5.8	5.8	FY 1986
NSLS Beam Line & Support, BNL (84-ER-111)	2.5	10.0	19.7	FY 1986
Center for Advanced Materials, LBL (84-ER-112)	1.8	10.8	40.2	FY 1988
Stanford Synchrotron Radiation Laboratory Enhancement (85-ER-402)	1.2	9.1	12.9	FY 1986
Kansas State University Ion Collision Physics Facility (85-ER-403)		2.0	3.4	FY 1987
Total		$40.1		

and Accelerator Improvement Project (AIP) requirements. The request in FY 1985 includes a significant increase in GPP funds as a result of the BES program assuming GPP funding responsibility for the Argonne National Laboratory. Previously this funding was provided by the Assistant Secretary for Nuclear Energy. This item accounts for $5.0 million of the $5.8 million GPP request in FY 1985.

This completes my summary of the BES program. I would now like to discuss the Magnetic Fusion Energy program.

MAGNETIC FUSION ENERGY

As a long-term energy option, magnetic fusion could become a principal energy source in the next century. Its potential attractiveness is based upon such characteristics as an inexpensive, vast and secure fuel reserve, environmental and safety aspects that appear to be acceptable, and promising results from scientific research in the U.S. and abroad. Fusion development also contributes important technology advances that provide near-term benefits in fields as diverse as superconducting magnets, high power accelerators and radiofrequency systems, advanced materials development, and mathematical methods for computers.

The goal of Federally-supported, long-term R&D is to develop promising technological concepts to the point where private enterprise can reasonably assess their risks. Accordingly, the Department's Magnetic Fusion Energy (MFE) program is developing the technical data base required for the private sector to determine the commercial potential of fusion. The program is being carried out in such a way as to maintain an international leadership role for the U.S. in fusion research.

In support of the technical data base goal, the program's intermediate objectives are the development and operation of facilities in which fusion research is conducted, the definition of an attractive reactor confinement concept and the development of critical technologies required to demonstrate engineering feasibility. This work is being done through a base program of research in magnetically confined plasmas, including tokamaks, tandem mirrors, and other supporting concepts. The objective is to select a suitable fusion plasma core for an eventual fusion reactor.

The two leading confinement concepts being pursued are a closed magnetic confinement system referred to as a toroidal system and an open system referred to as a mirror system. The toroidal system uses doughnut shaped devices wrapped with electrical coils that produce a closed magnetic field.

There are several kinds of toroidal devices including tokamaks, stellarators, reversed field pinch systems, and compact toroids. Tokamaks are the devices being examined most extensively both in the U.S. and internationally. The majority of the tokamak research is conducted at the Princeton Plasma Physics Laboratory (PPPL), GA Technologies, Oak Ridge National Laboratory (ORNL), and the Massachusetts Institute of Technology (MIT). The second leading concept is an open magnetic confinement system referred to as a mirror system. Mirror devices have cylindrical center sections with large magnets at each end that reflect the plasma particles toward the center to prevent their escape from the open ends. The major laboratory for mirror research is the Lawrence Livermore National Laboratory (LLNL). Additional mirror experiments are conducted at MIT, the University of Wisconsin, and TRW.

Presently the tokamak is the most developed confinement concept followed by the more recently developed tandem mirror. The tokamak program will be ready by late 1986 to attempt production of reactor grade plasmas using deuterium/tritium fuels at the Tokamak Fusion Test Reactor (TFTR), which recently began operation at Princeton. The Mirror Fusion Test Facility (MFTF-B), which is under construction at Livermore, will investigate by the late 1980's the physics of a reactor-grade mirror plasma using deuterium as a fuel.

There has been general agreement among the fusion scientific community and advisory groups that a next logical program step, generally designated as the Tokamak Fusion Core Experiment (TFCX), should produce a near reactor grade ignited plasma in a long pulse device. There is further agreement that sufficient technical information and program capability now exist to begin designing this next device. Systems studies of various TFCX options are now underway, with the Princeton Plasma Physics Laboratory and the Fusion Engineering Design Center playing the major roles. The results of these studies will be factored into a DOE decision concerning the device that follows TFTR.

During FY 1983-84, fusion research on the leading concepts and on technology development led to many technical accomplishments. In tokamak research:

- The most outstanding tokamak experimental achievement in 1983 was the attainment of a value for the confinement parameter (defined as the product of density and energy confinement time) above the minimum value required for proof of fusion's scientific feasibility. This result was obtained in the Alcator C confinement device at MIT at densities several times greater than those expected in a fusion reactor.

- The TFTR device, which is designed to achieve energy breakeven, thus proving fusion's scientific feasibility, began experimentation for the first time in FY 1983. Initial experimental results have been extremely encouraging with world record energy containment times of nearly 300 milliseconds.

- The Princeton Large Torus at PPPL demonstrated that the tokamak plasma current can be started and maintained using radiofrequency waves. Although the current drive efficiency in these groundbreaking experiments, when extrapolated to reactor densities, was a little too low for true steady state reactor use, these results provide an expanded experimental foundation for designing tokamak reactors with sufficiently long pulse lengths that loss of strength in construction materials due to cyclic fatigue is not a problem.

In the mirror confinement concept:

- The existence of a thermal barrier was confirmed for the first time in the Tandem Mirror Experiment Upgrade at Lawrence Livermore National Laboratory. This long-sought achievement greatly improves the potential economics of mirror reactors.

- A major accomplishment at the Tandem Mirror Experiment (TMX) device at LLNL showed the technical feasibility of the "Yin-Yang" concept. This configuration consists of two "C" shaped interlocking magnets which produce a magnetic mirror. The TMX tests were carried out successfully without excessive particle escape or the plasma instabilities that could lead to reactor instabilities. Also, for the first time, TMX startup was achieved using only radiofrequency plasma heating, the startup technique most likely to be used in a reactor.

In the area of technology development, progress was made with the demonstration of the efficient production and release of tritium in a solid tritium breeding experiment. Such solid breeders would improve the safety of fusion systems. The processing of tritium is being studied in the Tritium Systems Test Assembly. Other accomplishments included the completion of a test to show how large amounts of lithium can be handled safely, the setting of several world records in the development of components needed to heat fusion plasmas (i.e., neutral beam injectors, gyrotron tubes, pellet injectors), and continued progress in developing component hardware that will be needed for fusion experiments. The Large Coil Test Facility (LCTF) at Oak Ridge National Laboratory and three of the six large superconducting magnets (coils) for use in the facility were completed. Two of the 40 ton coils were installed in the LCTF vacuum tank in preparation for an initial two coil test in early 1984.

During the last year, international cooperation continued to play an important role in the United States' fusion program. Areas of cooperation included sharing research data, joint planning of comprehensive research programs in selected areas, and joint funding and hardware support for major scientific and technological projects. The European Community and Japan are major participants in these activities. Active scientific information exchanges also are continuing with researchers in the Soviet Union.

In September 1983 senior government officials responsible for fusion policy matters participated in the Versailles Summit of Industrial Nations to consider strengthening joint planning and collaboration in fusion energy research. Bilateral activities also were pursued in 1983 and included the signing of an agreement for a joint effort by the U.S. and Japan in the area of materials irradiation activities. Experimental time on the ORNL High Flux Isotope Reactor and use of the Oak Ridge Reactor facilities will be involved in this research. In addition, DOE and the Japanese Atomic Energy Research Institute extended for five years their joint project in tokamak research on the Doublet III facility at GA Technologies.

Finally, an agreement of cooperation between the U.S. and the Peoples Republic of China (PRC) was signed in 1983.

The strategy used to implement the ongoing MFE program has three phases: scientific feasibility, product definition and product development. The current plan is to attempt to demonstrate scientific feasibility in the TFTR in late 1986. This will occur when energy breakeven is attained (i.e., when the amount of energy released from fusion reactions equals the amount of energy required to heat the plasma).

As confidence increases in our ability to accomplish the objective of the first phase, the program has begun to address the issues of the product definition phase. The objective in this second phase is to identify a reactor core plasma confinement concept that is credible in both a scientific and technological sense. This objective is in keeping with the program's goal of developing the technical data base required for the private sector to determine the commercial potential of fusion. There are two major thrusts in the program to achieve this objective. On one hand, we must confront the issues of burning plasmas in a TFCX-like facility. On the other hand, we must strengthen the search for innovative magnetic configurations that have improved potential for practical application. The third phase, product development, would begin after selection of a fusion plasma concept.

FY 1985 BUDGET REQUEST

The FY 1985 budget request for Magnetic Fusion Energy is $483.1 million. This represents an increase of $12.3 million over the FY 1984 level. The request includes $417.2 million for Operating Expenses, $33.4 million for Capital Equipment funds and $32.5 million for Construction projects (Table 10).

At current funding levels, the program will continue physics research aimed at developing the two most advanced concepts, tokamaks and tandem mirrors, as well as a technology development program to support the base scientific program. In addition, support is provided for developing alternate concepts which contribute to the general base of technical knowledge underlying the main concepts. The requested level of funding will allow us to address the key physics issues related to heating, confining, and controlling a plasma as well as the reactor technology and design issues associated with a long pulse ignited tokamak. The technology issues include plasma production, reactor components, and system designs. Existing facilities will be used to pursue key technical issues of confinement physics and engineering development. Together, these physics and technology research efforts will provide a base program moving toward the objective of developing a commercially attractive reactor concept.

Table 10
Magnetic Fusion Energy
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Operating Expenses	$396.5	$417.2
Capital Equipment	37.8	33.4
Construction	36.5	32.5
Total	$470.8	$483.1

The Magnetic Fusion Energy budget is organized into five interrelated functional areas that form the basis of a unified and balanced effort to conduct the research and development necessary to define a practical fusion product. The Confinement Systems and the Applied Plasma Physics subprograms, working in conjunction, provide the physics base for the MFE program. In the near term, the primary driving force of that program flows from the experiments conducted in the Confinement Systems subprogram, with its dual focus on toroidal confinement systems and mirror confinement systems. The Applied Plasma Physics (APP) subprogram analyzes these results, develops plasma physics theories and models to explain the experimental results and suggests directions for additional investigations. Based on this information, the APP subprogram also initiates experimental and theoretical investigations of basic physics problems related to alternate confinement concepts and develops diagnostic instruments for use by the Confinement Systems subprogram.

Using information developed by the above subprograms, the Development and Technology subprogram develops components and systems for use in near- and mid-term fusion experiments as well as long-term generic materials development. This subprogram also performs conceptual design studies for fusion power reactor concepts. These design studies serve to identify component and system development needs that must be undertaken to prepare for the eventual commercialization of fusion.

In carrying out the assignments of the physics and technology tasks, needs for major new facilities are identified from time to time. The Planning and Projects subprogram provides for construction of major new facilities and fabrication of auxiliary components for these facilities. Finally, the Program Direction subprogram includes the funding to cover salaries, benefits, travel, and associated expenses of the Headquarters Office of Fusion Energy. The proposed budget levels for these areas are indicated in Table 11.

In Confinement Systems, Operating Expenses funds of $154.1 million are provided to support toroidal systems and $42.1 million to support mirror systems. A major portion of the toroidal systems budget provides for the cost of conducting experimental operations on existing devices including: Alcator C at MIT, the Princeton Large Torus/Princeton Bean Experiment (formerly the Poloidal Divertor Experiment) at Princeton, and Doublet III at GA Technologies. In addition, funds will be used to prepare the TFTR for the world's first demonstration of magnetic fusion scientific feasibility by achieving energy breakeven in 1986. Fabrication of the Advanced Toroidal Facility at ORNL and modification of the Doublet III facility in cooperation with the Japanese to enhance the capability of this machine will continue in FY 1985.

Table 11
Magnetic Fusion Energy
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Operating Expenses		
Confinement Systems		
Toroidal Confinement Systems	$144.2	$154.1
Mirror Confinement Systems	43.9	42.1
Applied Plasma Physics	76.8	84.5
Development & Technology	78.3	79.6
Planning and Projects	48.7	52.8
Program Direction	4.6	4.1
Subtotal	$396.5	$417.2
Capital Equipment	37.8	33.4
Construction		
Fusion Materials Irradiation Test Facility	0.0	3.0
Mirror Fusion Test Facility-B	30.0	20.1
General Plant Projects	6.5	9.4
Subtotal	$ 36.5	$ 32.5
Total	$470.8	$483.1

In mirror confinement systems, the funds will be used to support the operation of the Tandem Mirror Experiment-Upgrade at LLNL, the first full year of operation on TARA at MIT and several other smaller devices to extend the technical data base of tandem mirrors. Preparation for the operation of MFTF-B will also be initiated in FY 1985. Mirror confinement systems also includes support for the Elmo Bumpy Torus (EBT) concept which involves toroidally linked mirrors. Work on EBT will be directed toward continued studies of fundamental issues of physics (e.g., electron cyclotron heating and confinement) in support of the tokamak and tandem mirror programs.

The Operating Expenses budget request for the Applied Plasma Physics subprogram is $84.5 million. This includes support for fusion theory, experimental research on smaller scale tokamaks and mirrors, development of new diagnostic techniques required to understand experimental behavior, development of supporting concepts with potentially superior reactor prospects and operation of the Magnetic Fusion Energy Computer Network which provides all the large scale computing capability used by the fusion program for data analysis, theoretical modeling and design.

The Development and Technology subprogram will be supported in FY 1985 at a level of $79.6 million in Operating Expenses. This will include work on necessary plasma and reactor technologies as well as design of reactor systems. A conceptual design for a long pulse ignited tokamak will be carried out by redirecting efforts from within the program. Specific technology development issues include plasma heating; plasma fueling; impurity and exhaust control; first wall, structure and heat flux materials; blanket and shield systems; superconducting magnets; and remote maintenance. The major facilities for technology development which will be funded in FY 1985 include the Large Coil Test Facility and Rotating Target Neutron Source II Facility at ORNL and the Tritium Systems Test Assembly at LANL.

The Planning and Projects subprogram Operating Expenses request is $52.8 million. This includes completion of work on the Tokamak Flexibility Modification project for TFTR to ensure achievement of the basic TFTR objectives. An increase is provided for development support and fabrication of auxiliary components on MFTF-B which will allow for experimental startup in the third quarter FY 1987. Funding is also requested to provide the necessary development support on the Fusion Materials Irradiation Test Facility (FMIT).

The FY 1985 level for Magnetic Fusion Energy Program Direction is $4.1 million. These funds are required to provide for the salaries, benefits, travel, and other expenses associated with 66 full-time equivalents.

CAPITAL EQUIPMENT

The request for capital equipment is $33.4 million. This represents a decrease of $4.4 million in funding support and provides a level commensurate with the operating program described above. These funds are used to support the execution of the research program. Most of these funds will be used to procure hardware to enhance the effective and efficient utilization of the fusion experimental devices. The remainder of the funds are used to maintain existing equipment or upgrade and replace obsolete equipment.

CONSTRUCTION

The Construction budget provides $3.0 million for FMIT, $20.1 million for the MFTF-B, and $9.4 million for General Plant Projects (GPP) (Table 12). FMIT will provide the capability to determine the effects of the fusion reactor neutron environment on candidate materials for future fusion reactors. The FMIT funding provides for the restart of construction activities and is predicated on international funding being available. MFTF-B is a thermal barrier tandem mirror device which will be the largest experimental facility in the world capable of investigating the mirror fusion concept. The requested funding for MFTF-B is based upon completion of facility construction in the fourth quarter of FY 1986. The

Table 12
Magnetic Fusion Energy
Budget Authority
($ in millions)

Construction	Prior Years	FY 1985 Request	TEC	Completion Date
Mirror Fusion Test Facility-B	$217.5	$20.1	$246.6	FY 1986 (4th qtr.)
Fusion Materials Irradiation Test Facility	44.7	3.0	77.5 1/	FY 1988 (4th qtr.) 1/
General Plant Projects	N/A	9.4		
Total Construction		$32.5		

1/ U.S. funds only. $67.0 million of anticipated foreign contributions, based on an assumption that an agreement is reached with foreign participants for them to fund 2/3 of the remaining construction costs, results in a total cost of $144.5 million.

increase in GPP funding of $2.9 million reflects the institutional requirement to reduce the overall backlog of general plant projects at Oak Ridge National Laboratory.

Let me turn now to the Biological and Environmental Research program.

BIOLOGICAL AND ENVIRONMENTAL RESEARCH

The Biological and Environmental Research (BER) program represents the Nation's only long-term research effort specifically focused on energy-related health and environmental issues. There are two major goals of this research program. The first is to provide, through basic and applied research, sound, scientific data required to reduce the health and environmental uncertainties associated with the development of energy technologies and weapons systems required to meet the Nation's future energy and national security needs. The second goal is to develop new applications of nuclear science and technology for use in the diagnosis and treatment of human diseases.

This research program began 35 years ago to look at ways of measuring radiation, understanding the major processes that move radionuclides back through the environment to humans, and investigating how radiation affects human health. Now, a number of years later, it is apparent that many of the same biological questions that have been investigated in radiation-related research must also be addressed with respect to the effects of energy-related chemicals on human health (e.g., what is the impact of wastes from synthetic fuels on mutation rates and cancer incidence, on reproductive functions and on critical organ systems like the lungs and bone marrow). The same processes in the environment, the same interactions at the cellular level, and the same types of damage to DNA and other cell components are characteristic of other energy-related pollutants as well.

Information obtained as a result of this research program has provided the basis for a wide range of applications, including developing cost-effective protection standards for the nuclear industry, providing reliable, comprehensive data on the effects of fallout from weapons testing at the Nevada Test Site and the Marshall Islands, and developing strategies for control of emissions from processes used for conversion of coal to synthetic oil and gas.

The Nuclear Medicine program has changed the practice of medicine by developing techniques and instrumentation critical to the diagnosis and treatment of human disease. By exploiting the Department's unique capability in high energy physics, radiation chemistry and isotopes separation, the BER program has shown that it is feasible to use a broad array of radioactive and stable isotopes, labeled pharmaceuticals and radiation sources in the diagnosis and treatment of human disease and in biomedical research.

The BER program employs multidisciplinary "teams" of individuals in specialized facilities that have come to be regarded as national resources for research in the biomedical and environmental area. For example, in FY 1984 other Federal agencies and other DOE programs are investing over $100 million to use BER's facilities to conduct research important to achieving their goals. Nearly one third of the research supported by the BER program is conducted on academic campuses.

Over 200 BER-funded scientists in DOE laboratories hold academic appointments and serve as an important resource in the formal education of the Nation's scientists, engineers, and physicians. Many of the research projects supported at the laboratories also serve as vehicles for the training of pre-doctoral students as well as post-doctoral investigators.

The BER program places heavy emphasis on basic research. It evaluates the health consequences of energy activities within the context of the overall environment and at all levels of biological organization. It focuses on long-term generic issues rather than near-term process-specific questions which industry and regulatory agencies are better able to address. Most importantly, it takes an anticipatory rather than a regulatory approach toward the identification and solution of potential health and environmental problems; that is, it tries to identify the potential issues or problems in advance and determine the magnitude of the effect, if any, so these problems can be eliminated or controlled.

Because of the long-term nature of much of the BER research and the challenges of designing and implementing research that will yield timely and cost-effective information, there is a need for outside expert advice in program planning and evaluation. On November 22, 1983, the Health and Environmental Research Advisory Committee was chartered by the Department to meet that need. The expert advice obtained from the Committee will help us shape the strategic long-term planning necessary to establish research priorities, identify funding requirements, determine proper program balance and identify opportunities regarding interagency cooperation and industrial participation.

FY 1985 BUDGET REQUEST

The budget request for FY 1985 for the Biological and Environmental Research program is $189.1 million. Within this budget, $178.1 million is for Operating Expenses, $8.0 million is for Capital

Equipment, and $3.0 million is for Construction (Table 13). Funding by various areas is shown in Table 14. I would like to take a moment now to summarize the FY 1985 request.

A major objective of the BER research program is to understand and to reduce the potentially harmful effects on humans and the environment that are associated with energy technologies. In order to estimate health effects, we must first be able to determine the exposure received by humans or the environment. The Source and Dose Determination program activity, with an FY 1985 budget request of $10.3 million in Operating Expenses, conducts research to improve techniques to measure human exposure to ionizing radiation and to energy-related chemicals, to develop new measurement instrumentation and to define the physical and chemical nature of biologically active agents associated with energy technologies. These latter studies provide the data necessary to understand how these agents move through the environment and to estimate human exposure to them.

Once the source of a pollutant and its biologically active agents are identified, the Environmental Fate and Behavior program activity focuses on the pathways and mechanisms by which these agents move through the environment. With an FY 1985 budget request of $32.7 million in Operating Expenses, this activity includes atmospheric, aquatic and terrestrial research that will

Table 13
Biological and Environmental Research
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Operating Expenses	$173.2	$178.1
Capital Equipment	8.3	8.0
Construction	2.4	3.0
Total	$183.9	$189.1

Table 14
Biological and Environmental Research
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Late Effects on Health & Envir. of Energy Development & Use		
Source and Dose Determination	$ 10.2	$ 10.3
Environmental Fate & Behavior	28.3	32.7
Health Effects	62.6	57.3
Basic Biology	22.9	28.2
Risk Analysis	1.8	0
Nuclear Medicine	19.7	20.7
Carbon Dioxide Research	12.5	13.4
Program Direction	3.6	3.5
Facility Operations	22.3	23.0
Total	$183.9	$189.1

contribute to our ability to determine the probability of human exposure and the potential impact on human health and the environment. In FY 1985 we intend to mount a research program to investigate how changing the emissions of the SO_2 and NO_x that eventually enter storm clouds might affect the acidic deposition (acid rain) that falls from those clouds. We will be particularly concerned with whether a given reduction in emissions from the source will result in a proportional reduction in rain acidity over ecologically sensitive regions. If successful, the results of this research will have significant implications for the design of effective and economical emission reduction strategies.

The Health Effects program activity, for which $57.3 million in Operating Expenses is requested in FY 1985, is aimed at developing a solid base of knowledge to increase our understanding of human health risks that may result from exposure to ionizing radiation or to energy-related chemicals. Using some of the techniques developed in the Source and Dose Determination program activity, this activity emphasizes research on cancer, inheritable defects and other delayed or late occurring health effects that may be associated with chronic, low dose exposures. This comprehensive program of health effects research is composed of a family of interrelated studies of humans, animal species and molecular and cellular systems.

Research in Basic Biology, for which $28.2 million in Operating Expenses is requested in FY 1985, is aimed at developing an understanding of the generic biological mechanisms that underlie human health effects of radiation and energy-related chemicals. To achieve this objective, research is carried out in structural biology, molecular biology and cell biology. To take advantage of new opportunities provided by recent advances in molecular and cellular biology and related fields, our basic research efforts will be expanded and refocused in FY 1985. There will be decreased emphasis on studies in bacterial and other lower level biological systems (such as yeast) and additional resources will be applied to ongoing and new investigations using mammalian cells, with specific emphasis on human cellular systems. There will be increased emphasis on improving the basis for extrapolation of experimental data to humans; and a strong program in DNA damage and repair will exploit recent advances to focus on a better understanding of human DNA repair capacity and its significance for human health.

The development and application of nuclear techniques for diagnostic purposes has changed the practice of medicine by reducing the need for invasive procedures and exploratory surgery. Our Nuclear Medicine Applications subprogram, for which $20.7 million in Operating Expenses is requested in FY 1985, has played an important role in these developments and continues to do so.

In FY 1985, the Nuclear Medicine Applications program will continue to provide new and improved sources of medically useful radioisotopes, new radiopharmaceutical agents, and improved instrumentation; and to demonstrate the feasibility of these various applications in clinical medicine. Once feasibility is established, these new technologies, instruments, and isotopic materials are taken over by the private sector for manufacture and distribution for patient diagnosis and treatment or by other research agencies or institutions to be used for the study of specific diseases.

In addition to research on radionuclides for medical use, considerable work will continue to produce existing stable isotopes for use in biomedical research and medicine, to improve instrumentation for their detection and measurement and to evaluate the feasibility of using new stable isotopes in medical research and diagnosis.

Research would also be supported to provide information necessary to evaluate the feasibility of using neutron capture techniques for the treatment of cancer; synchrotron light for improved diagnosis of coronary artery disease; heavy ions for the treatment of brain lesions; and shaped radiofrequency electromagnetic fields to treat cancer and abnormalities of the eye.

Within the Federal Government, the Nuclear Medicine Applications mission and DOE's facilities for conducting research in this area are unique. Liaison is maintained with Federal agencies (principally the National Institutes of Health and the Food and Drug Administration), the radiopharmaceutical industry, and the medical community regarding the requirements and the effective use of these techniques in medical research and practice.

The goal of the Carbon Dioxide Research program, which is budgeted in the BER program but managed by the Basic Energy Sciences program, is to develop a sound, quantitative atmospheric carbon dioxide knowledge base to aid in energy policy decision making. We must improve our understanding of the fundamental scientific relationships between CO_2 concentration and climate. This can only be accomplished by increased data collection, improved measurements and development of reliable models.

The FY 1985 budget request of $13.4 million in Operating Expenses for the Carbon Dioxide research program provides for completion of the State of the Art and Statement of Findings reports. These reports, scheduled for publication in early 1985, will delineate what is known, unknown and uncertain about atmospheric CO_2, possible CO_2-induced climate changes and CO_2 vegetation effects. This effort will provide a better understanding about the long-term implications of CO_2 and will redefine the research necessary to provide a sound base for policy decisions.

In FY 1985, research into the effect of other trace (greenhouse) gases will be carried out. These gases, such as methane, freon and nitrous oxide, act similarly to CO_2 in affecting the return of radiation to space. Recent studies have indicated that these gases may have an effect ranging from half to equal that of CO_2's effect on the climate. Thus, in the analysis of climate effects from CO_2, these other gases must be included or a significant error could occur in our estimation of the magnitude and timing of climate change.

The FY 1985 budget request does not include funds for the Risk Analysis subprogram. A number of risk analysis documents have been produced. They currently are being reviewed and will be completed in FY 1984.

The national laboratories and other specialized laboratories (e.g., Inhalation Toxicology Research Institute, the Environmental Measurements Laboratory) supported by the BER program represent an impressive national resource of skilled investigators, advanced major scientific instrumentation and exceptional, specialized research facilities. They provide the ability to address the diversity of research issues previously described while resulting in additional benefits to the scientific community at large.

But these facilities require continued commitment to operate, equip, and maintain them. The FY 1985 request for Facilities Operations includes $12.1 million in Operating Expenses for diverse special resources, including cyclotrons and reactors, environmental research parks and measurement laboratories as well as advanced spectrometers, electron microscopes, synchrotron light sources, and flow cytometers.

A Capital Equipment request of $8.0 million is required to maintain state-of-the-art capability for ongoing research and for equipment to initiate new research efforts.

The FY 1985 Construction request of $3.0 million is required to support the program's General Plant Project needs including the Pacific Northwest Laboratory landlord responsibility. These General Plant Projects will provide facilities for conducting critical research programs, contribute to greater efficiency, eliminate health and safety hazards, and will reduce maintenance and operational costs.

I would now like to discuss the several ER outlay programs that are related to my statutory responsibilities to advise the Secretary on DOE energy R&D programs, the non-weapons multiprogram laboratories and the education and training of scientists and engineers.

ADVISORY AND ASSESSMENT ACTIVITIES

Within the Office of Energy Research, the Office of Field Operations Management (FOM) and the Office of Program Analysis (OPA) support the Director's advisory responsibilities. The Office of Field Operations Management provides support with regard to oversight of the laboratories and energy-related manpower development and training activities. This Office has developed several management tools used by the Department in administering its laboratories and R&D facilities across the country. It also continues to manage the University Research Support, the University Research Instrumentation and the Multiprogram General Purpose Facilities programs, all of which I will discuss shortly. The Office of Program Analysis, on the other hand, provides independent and objective program analyses and technical assessments under the Energy Research Analyses program. The FY 1985 budget request for these four programs is shown in Table 15.

ENERGY RESEARCH ANALYSES

With an FY 1985 budget request of $3.0 million, the Energy Research Analyses program provides the Department with a capability for

Table 15
Energy Research Analyses, University Research Support,
University Research Instrumentation, Multiprogram General Purpose Facilities
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Operating Expenses		
Energy Research Analyses	$ 2.9	$ 3.0
University Research Support	5.5	9.2
University Research Instrumentation	4.0	6.0
Construction		
Multiprogram General Purpose Facilities	42.1	39.0

independent analyses of its technical needs and opportunities. It is carried out by the Office of Energy Research (ER) through studies, workshops, panels, and other mechanisms that allow the Department to make use of the best talent available from the industrial and academic sectors as well as the national laboratories. The specific functions of this program include assessing DOE's long range technology base and ongoing R&D programs, providing coordination and direction for interagency activities such as acid rain, coordinating resolution of major technical issues and research policy developments, and providing support to DOE advisory groups such as the Energy Research Advisory Board.

Recent accomplishments in the area of technical assessments included completion of two major program assessments, one of university and laboratory research projects in the Office of Fossil Energy's Enhanced Gas and Oil Recovery Program and the other of the accomplishments of ER's Biological and Environmental Research (BER) program. The latter assessment documented tangible contributions to the public made by the BER program. A narrative of these accomplishments is now available.

Assessments of research needs and priorities regarding photovoltaic cells and the solar thermal and geothermal programs were also completed. These independent reviews by outstanding researchers provided peer guidance on the most fruitful directions for future DOE research. An assessment was made of solar and building control research projects supported by DOE at the National Bureau of Standards. This work was found to be of high quality and appropriate for support by the public sector. Finally, an assessment of the need to continue the DOE High Altitude Sampling Program was completed.

OPA continued to represent DOE on the Interagency Task Force on Acid Precipitation and to coordinate the DOE acid precipitation research program with other Federal agencies. In FY 1983, DOE and the Environmental Protection Agency entered into a Memorandum of Understanding (MOU) initiated by OPA. The MOU formalized the joint assessment efforts of the two agencies and established the Acid Deposition Assessment Staff to which OPA continues to provide manpower and financial support. In addition, OPA conducted extensive technical contributions to documents used by those who formulate the Administration's acid rain policy.

The FY 1985 budget request would provide up to four technology assessments depending on their complexity and depth and up to four program assessments. Technical coordination and guidance will continue in the areas of acid rain and civil remote land sensing; liaison responsibilities will continue with the International Energy Agency to maintain annual reviews of energy R&D priorities, programs and technology base. The program will also provide independent peer review of technical or research subjects as requested by principal Secretarial Offices or the Director of Energy Research, and will continue to support the Energy Research Advisory Board.

UNIVERSITY RESEARCH SUPPORT

The University Research Support Program (URS) provides a budget and management focus for a small number of specialized research and manpower development activities which help strengthen the capabilities of both universities and the Department's laboratories to carry out longer range scientific and technical research. Through these interrelated efforts, the Department is working to:

- o Maintain and strengthen university-based energy research and manpower development efforts in selected high priority energy research fields.
- o Utilize the unique resources of the national laboratories (equipment, instrumentation, and personnel) to assist university faculty and students to carry out advanced research and related training.

- Increase the number of students including women and minorities pursuing professional level degrees in energy-related science or engineering.

- Enhance the quality of the scientific/technical workforce in the Department's national laboratories.

The URS program, with an FY 1985 budget request of $9.2 million in Operating Expenses, consists of two major subprograms (Table 16). The first subprogram, University/National Laboratory Cooperative Research, is directed at strengthening the capabilities of both universities and national laboratories as major energy research performers in the conduct of long range energy research. Many of the activities supported within this subprogram involve joint efforts between university and laboratory-based researchers. With a FY 1985 budget request of $8.4 million, this subprogram supports both University Laboratory Cooperative Research and University Reactor Fuel Assistance. This latter activity is aimed at ensuring that a continuing fuel supply is available for operation of university research reactors.

We are requesting a significant increase ($3.0 million) for the University Laboratory Cooperative Research activity. This program serves as an essential bridge, and will strengthen the ties,

Table 16
University Research Support
Budget Authority
($ in millions)

	FY 1984 Estimate	FY 1985 Request
Operating Expenses		
University/National Laboratory Cooperative Research		
University Laboratory Cooperative Research	$ 3.5	$ 6.5
University Reactor Fuel Assistance	1.5	1.9
Subtotal	$ 5.0	$ 8.4
Energy Manpower Development		
Energy Manpower Assessment	$ 0.3	$ 0.5
Energy Education & Training	0.2	0.3
Subtotal	$ 0.5	$ 0.8
Total University Research Support	$ 5.5	$ 9.2

between the laboratory and university communities. Laboratories are important complementary resources in preparing students for future research careers. This budget request will allow us to double the number of undergraduate students supported in summer research programs. It also will allow us to develop additional cooperative research programs involving university faculty and graduate students and laboratory scientists.

The second subprogram, Energy Manpower Development, with a FY 1985 budget request of $0.8 million in Operating Expenses, combines two manpower-oriented activities. The Manpower Assessment activity conducts assessments and analyses of the supply and demand of manpower for both current and future energy R&D programs; and Energy Education and Training supports activities directed at encouraging secondary school students to pursue energy-related science and engineering programs at the college level.

The FY 1985 budget request of $9.2 million in Operating Expenses will allow these programs together to:

o Support approximately 3000 student and faculty research participation appointments and special training activities at the Department's national laboratories and major contractor facilities,

- Refuel up to six university research/training reactors and support approximately 18 reactor sharing projects,
- Update manpower assessments for future professional level manpower requirements (e.g., scientists/engineers) for Departmental research programs,
- Support cooperative projects with universities, industry and the Department's national laboratories through the Prefreshman Engineering Program designed to encourage secondary school students to pursue energy-related engineering and science programs during their college careers, and
- Support 6-8 high school science and math teacher institutes in computer science and energy-related subjects at the DOE national laboratories.

UNIVERSITY RESEARCH INSTRUMENTATION

The continued improvement of energy technologies depends on the development of new knowledge and concepts that can be applied to energy-related materials and processes. The research that leads to this new knowledge requires advanced, state-of-the-art equipment.

The types of instruments required for advanced energy research include such equipment as plasma emission spectrometers which will detect and identify materials at the parts per billion level, a variety of scanning microscopes which can be used to obtain greater understanding of surface states and features, and hydrothermal equipment which enables one to simulate the temperatures and pressures which are found deep within the earth and in ocean depths. These and related instruments are very expensive, generally on the order of several hundred thousand dollars, and thus beyond the means of nearly all research universities to finance directly.

In recent years the Department has attempted to help universities obtain access to these and similar sophisticated research instruments by (1) making the equipment at its national laboratories available to university researchers, (2) establishing unique user-oriented research facilities such as the Combustion Research Facility at the Sandia Laboratory at Livermore and (3) providing some funds within research contracts for the less expensive research tools. None of these programs, however, meets the needs of university scientists for continuous availability of the type of equipment which is provided through this program.

DOE's University Research Instrumentation program, with an FY 1985 budget request of $6.0 million in Operating Expenses, will focus on those university groups that have demonstrated expertise in one or more of a small number of energy-related topics which are of special concern in the Department's long-range research efforts. Among the research topics likely to be of concern in FY 1985 are combustion, bioconversion related to energy, nuclear waste isolation systems, catalysis, advanced materials science and engineering, and the transport of energy-related pollutants. It is estimated that the $6.0 million requested will enable the Department to assist about 10-20 institutions to obtain the expensive (i.e., over $100,000) specialized instrumentation required.

The program will continue to be coordinated, including both proposal review and awards, with similar programs in the other Federal agencies such as DOD and NSF. The close coordination ensures that each agency's program complements and reinforces the research efforts of all the agencies and makes each program more cost effective.

MULTIPROGRAM GENERAL PURPOSE FACILITIES

The FY 1985 Construction request for the Multiprogram General Purpose Facilities (MGPF) program is $39.0 million (Table 17). The goal of this program, which is managed for the Department by the Office of Energy Research, is to rehabilitate and replace

Table 17
Multiprogram General Purpose Facilities'
Budget Authority
($ in millions)
FY 1985 Proposed Projects

Construction	FY 1985 Request
Central Chilled Water Facility, BNL (85-R-701)	$ 3.5
Replace Laboratory Roofs, ANL (85-R-702)	3.5
Electrical Distribution System Restoration, ORNL (85-R-703)	1.1
Rehabilitate Underground Steam System, ANL (85-R-704)	3.0
Medical Facility Replacement, LLNL (85-R-706)	1.6
Replace Site Fire Alarm System, RL (85-R-707)	1.3
Establish a Central Chilled Water Plant, ANL (85-R-709)	1.0
Upgrade Environmental Monitoring, ORNL (85-R-711)	1.0
Modify Central Chilled Water Plant, ORNL (85-R-712)	1.0
Prior Year ongoing projects*	22.0
Total	$39.0**

*See Table 18 for additional detail on prior year ongoing projects.
**FY 1984 estimate for MGPF program is $42.1 million.

Table 18
Multiprogram General Purpose Facilities' Budget Authority
($ in millions)

	FY 1985 Request
Construction (ongoing projects)	
Security Facility, ANL (82-E-302)	$1.1
Rehabilitate Power Systems, INEL, LLNL, RL,ORNL (83-E-308)	2.8
Electronics Facility. ANL (83-E-309)	3.2
Utility Replacement & Upgrade, BNL (83-E-310)	3.2
Rehabilitate Old Town Utilities, LBL (84-ER-101)	3.8
Cooling Water Facility Rest., ORNL (84-ER-102)	3.4
Road Repair, LBL, INEL, RL, ANL (84-ER-103)	4.5
Subtotal Ongoing	$22.0

multiprogram general support facilities that are essential to continued operations of the Department's multiprogram laboratory sites. These support facilities include site utilities and support buildings such as laboratories, office buildings and warehouses, roads and railroads, which represent a multibillion dollar government investment.

Through continued use and aging, support facilities deteriorate to a point where they are no longer capable of performing their intended functions and must be rehabilitated or replaced. The MGPF program systematically reduces the backlog of deficiencies of these support facilities. It reflects an appropriate Federal responsibility for management of the Government's real property, and ~~we~~ plan to continue the program as a necessary cost of doing business as long as the multiprogram laboratory facilities are used to perform research and development functions for the Department.

The FY 1985 budget request would continue construction on several projects begun in prior years, including rehabilitation of the Old Town area utilities at LBL, the upgrade of the cooling water facility at ORNL and improvements of roads at various laboratories. New projects proposed for FY 1985 would include rehabilitation or replacement of such facilities as an electrical distribution system (ORNL), an underground steam system (ANL), laboratory roofs (ANL), chilled water facilities (BNL, ORNL, ANL), medical facilities (LLNL), a fire alarm system (RL), and an environmental monitoring system (ORNL).

ADVISORY AND OVERSIGHT PROGRAM DIRECTION AND POLICY AND MANAGEMENT

The FY 1985 budget request for Advisory and Oversight Program Direction is $2.9 million. These funds are required to provide for the salaries, benefits, travel and other expenses associated with 44 full-time equivalents. This FY 1985 request will provide the staffing resources required by the Director of Energy Research to carry out his responsibilities under legislation (P.L. 95-91) and those mandated by the Secretary in areas beyond the scope of other ongoing Energy Research programs.

The FY 1985 budget request for Policy and Management is $0.5 million. These funds are required to provide for the salaries and related expenses associated with 8 full-time equivalents in the Office of the Director of Energy Research.

Mr. Chairman, this concludes by testimony. I would be pleased to answer any questions at this time.

Senator DOMENICI. I appreciate it. Your possibilities might have run out before me. We might have run it out for you, but we appreciate it very much. We only have about a half-hour and we have to go vote. We would like to finish the first set of witnesses before that vote on prayer. So that is why I am delighted you have completed, because I am sure Senator Ford has some questions.

I have four and we will submit a couple to you in writing and then we would like to talk to you in an informal way at a later time about the computer access of DOE, computers in the country. I do not think we need to do it as part of this record. It is not terribly relevant to this hearing, but overall to us. The availability of information and the exchange of technology and the availability of this information is certainly something in which there is a growing interest in this country.

Let me just ask you with reference to the office of Health and Environmental Research, in 1981 this was about $189 million. Your request for this year is $176 million, if we do not include carbon dioxide research. This is what my staff tells us. Over the past several years we have been urging you to make some kind of difficult decisions in this area rather than distribute the cuts across the board, that you attempt to make some priority decisions and establish some long-term goals.

Last year it is my understanding that the funding was constant from the previous year and combined with the cuts you have proposed, which is not significant, but at least it is down rather than up, it seems that you are going to have to make some priority decisions and establish some goals in order to get some stability into the research programs themselves. Otherwise it would appear at least to me that they are going to be subject to so much misunderstanding as to where the next year is that you will lose some of its strength.

Could you give me your impression of where you are in this regard and when might we get a more secure process and set of goals for that particular office?

Dr. TRIVELPIECE. Mr. Chairman, last year at the time of this hearing, I indicated my intention and desire, based on a trip that I had taken to the various laboratories, to review these programs so that I could establish an advisory committee to include scientists in this area both from within the contractor population we support and outside of the department's contractor population. Everything in Government seems to take a little longer than you anticipate.

I had hoped to have that committee operating some time last summer and have the results of some of their deliberations available even hopefully before, or I would hope before the budget cycle for this year began. That hope was somewhat of a vain hope. However, I am pleased to announce that I was able to get a committee formed. That committee met yesterday for the first time. I have asked them to look into the 5-year program plan for biological and environmental research and make some recommendations back to the department before August of this year. In addition I have asked them to look into some of the technical aspects of epidemiology and chemical toxicology. There has been some debate within the administration as to the degree that the department should be involved in these activities.

I hope to use this type of outside committee to provide the scientific basis either for expanding our request or, if appropriate, contracting it but to do so from a point of view of sound scientific knowledge.

Senator DOMENICI. Would you submit the names of those people to the committee for the record? Clearly, I am not trying to interfere, but we would like to know who they are.

Dr. TRIVELPIECE. I would be glad to submit that as well as the charge letter that I have provided to that committee.

[The information follows:]

HEALTH AND ENVIRONMENTAL RESEARCH ADVISORY COMMITTEE

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*On sabbatical from the Lawrence Berkeley Laboratory until August 1984.

Department of Energy
Washington, D.C. 20585

MAR 19 1984

Dr. Mortimer L. Mendelsohn
Associate Director for Biomedical
and Environmental Research
Lawrence Livermore National Laboratory
P. O. Box 808
Livermore, California 94550

Dear Dr. Mendelsohn:

I recognize that a new committee needs time to pull its membership together and to become adequately informed regarding the program area of its responsibility. To that end, I would hope that you would employ several approaches, including briefings by program officials and opportunities to learn about the laboratory and off-site programs. However, time is of the essence if the Health and Environmental Research Advisory Committee (HERAC) is to influence the FY 1986 budget cycle. Accordingly, I would appreciate your accepting three specific assignments to make recommendations in areas where your advice is needed for FY 1986 program and budget planning:

1. The Office of Health and Environmental Research (OHER) has prepared a Plan for the Biological and Environmental Research Program, FY 1985-1990. Please review the Plan to advise us of your views regarding the goals, strategy, program scope, and specific research directions outlined in the Plan. In your deliberations please take into account legislative mandates, administration policy, the unique resources available in DOE laboratories, and the activities of other agencies and the private sector. What are your recommendations for preparation of subsequent versions of the Plan?

   I would appreciate your report on this topic by August 1, 1984.

For the following two topics, which address the more restricted areas of chemical toxicology and epidemiology, you may wish to appoint subpanels which report to you. If so, will you please appoint a chairperson from within the Committee together with other members, as appropriate, both from within and outside HERAC. To each subpanel you may appoint as many members as necessary (not to exceed twenty) to achieve the proper balance and scientific scope.

2. In the course of the transitions from the Atomic Energy Commission to the Energy Research and Development Administration to the Department of Energy, the scope of the OHER program greatly expanded from a focus on health and environmental effects of ionizing radiation to include multidisciplinary research on effects associated with fossil and renewable energy technologies. In recent years, the scope and direction of OHER's nonnuclear research program has come into question and the budgets in this area have undergone significant reduction. Budget decreases have been accompanied by a change in program orientation towards addressing broader generic issues common to many technologies, particularly health and environmental effects associated with complex chemical mixtures.

   Please review the OHER program on health and environmental effects of fossil fuels and complex mixtures (excluding research related to acid rain) and advise me on appropriate program directions and level of effort for DOE/OHER in this area. In your deliberations please consider national needs and the activities of other agencies and the private sector.

   I would appreciate your report on this topic by August 1, 1984.

3. OHER supports a number of studies in the area of epidemiology, including a long-term study of atomic bomb survivors in Japan which is carried out through the Radiation Effects Research Foundation (RERF). Although the individual projects have been peer-reviewed recently, there has been considerable ongoing discussion and attention devoted to some of the studies. Questions have been raised about the scientific value of some studies, and whether some were appropriate for DOE. Would you please assess the OHER epidemiology program and advise me on the need for and scientific merit of this work? Should these studies continue to be supported by DOE? Are there other energy-related human health issues which should receive higher priority? What directions should the RERF studies take in the future? Should support of this work be continued indefinitely? Are there other scientific approaches that should be employed in the RERF studies?

   I would appreciate your report on this topic by August 1, 1984.

Sincerely,

Alvin W. Trivelpiece
Director, Office of
Energy Research

Senator DOMENICI. Thank you very much. Now with reference to post-docs in our various national labs, clearly as you indicated while you are not charged in this area of educational enhancement, you play a very vital role. Can you discuss some of the areas where science and physics and math education are part of your program.

You know that I have maintained that we have a very high responsibility postdoctorate people for that period of time in between getting there and being able to fully intergrate the system. Even though we have been pushing very hard on that, there has been an increase in postdoctcrate in some of the labs in New Mexico but overall let me see if these numbers are right.

Biology and environmental science has dropped from 93 to 40 over 2 years and in the overall program from 355 in 1981 to 279. Now you are asking for additional——

Dr. TRIVELPIECE. It is about 294 in fiscal year 1983.

Senator DOMENICI. 294?

Dr. TRIVELPIECE. Yes; I do not remember the internal details, but the aggregate number that year was 294.

Senator DOMENICI. But it still is down.

Dr. TRIVELPIECE. Yes, it is down.

Senator DOMENICI. Now, you are requesting an increase in university research support in the budget but the interest in postdoctoral research is declining even with an increased request or would it go back up?

Dr. TRIVELPIECE. No, it would probably stay at about the same level. That includes some in the physics program, some in the chemistry program, some in the health and biology programs. We have from time to time within the administration also considered the possibility of expanding the fellowship program, and have to date been unsuccessful in trying to make a strong enough case to have that survive the internal budget deliberation process.

Senator DOMENICI. Do you have any way when you present that to measure the success of postdoctoral programs in your bailiwick versus others in the country, like NIH or the like?

Dr. TRIVELPIECE. No practical way that I am aware of. I might like to take a crack at doing that if you ask us to do, but I have not really thought of a way to try to evaluate it.

Senator DOMENICI. I do not know that I will ask you at this time. That may be very difficult. Let me just ask a more general question. My understanding is that the program is successful as measured generally by the scientific community. Is that a fair statement?

Dr. TRIVELPIECE. Yes, I think the postdoctoral programs do play a vital role in our Nation's education and training. How it works and whether it involves laboratories or people seeking teaching positions at academic institutions is different for different disciplines.

But I am not aware of any situation in which a postdoctoral program is not successful. I think it is more a question of how much one can afford and the circumstances under which it can be done.

Senator DOMENICI. There have been a number of articles—this is off on a completely different subject now, doctor—that address the possible dangers of proliferation from the fuel contained in our university research reactors. Some are suggesting that we need to modify the fuel in those reactors so as to decrease the amount of enriched uranium.

Does the Department consider this a threat or a real problem? Would the consequences be significant if we had to change the fuel in these educational reactors?

Dr. **Trivelpiece**. There is certainly a cost impact of doing this. There are something like 25 affected research reactors in the institutions around the United States, and it would cost something on the order of $15 million to convert them from highly enriched fuel to low enriched fuel. The impetus for this comes from the Nuclear Non-Proliferation Act as well as the Nuclear Regulatory Commission which has been taking up this issue.

We have testified before the Nuclear Regulatory Commission and expressed the Department's position and I have written to them identifying what the cost would be, to convert these reactors to low enriched fuel. Personally, I do not believe that there is a substantial risk. There is less than a formula quantity, that is, 5 kilograms of unirradiated material at any of these reactors at any time and they are used for research and teaching purposes.

The Nuclear Regulatory Commission is considering establishing orders that would require us to make that transition. We could do so for some fraction of them but should not for all of them, because some of them have been in the sense fueled for their lifetime and I think it would be ill-advised to take out the core from a lifetime fueled reactor and then replace it with low enriched fuel. It is not even clear that you could simply do it mechanically. Some design work would have to be done.

There are also some issues about relicensing and the like which would come into being. I do not know where the Nuclear Regulatory Commission is going to come out on their ruling. But my understanding is they may issue a proposed ruling any day, and we would have 60 days to comment on it.

Senator **Domenici**. One last question. We have a Meson physics facility that is funded through your nuclear sciences budget that is already in place, completed, a major American investment, in Meson physics used by diverse groups of institutions and users. Over the past years we have had to add money to the budget for its operation so as to maintain some constant level of utility. Could you provide us for the record a clarification as to whether the Department's budget covers the operating time anticipated or give us the information as to exactly what you think your request will accomplish versus the request that was made to the Department in terms of its utility and necessary op-time. Could you do that for us?

Dr. **Trivelpiece**. Yes.

Senator **Domenici**. You are aware that part of that problem is high utility bills that we have underestimated in the past?

Dr. **Trivelpiece**. Indeed.

[The information follows:]

Clinton P. Anderson Meson Physics Facility
Operations Table
(Budget Authority in Millions of Dollars)

	Actual FY 1983	Estimated FY 1984	President's Budget FY 1985	April 1983 Laboratory Request FY 1985
Cost of Facility Operations	$ 32.3[1/]	$ 33.5[1/]	$ 36.5	$ 41.8
Beam Hours for Research	3153	3100	2450	3350
Electric Energy Useage (1000's of megawatt hours)	132	140	110	152
Cost of Electric Energy	$ 4.9	$ 6.2	$ 5.3	$ 8.9

[1/] Includes Defense Programs support of LAMPF operations: $3.0 million in FY 1983 and $3.0 million in FY 1984.

Facility Operations includes costs of delivering beam for use by research scientists. It includes all costs of accelerator operations (including electric power) and maintenance and includes all costs of operation and maintenance of permanently installed equipment such as beam lines, beam dumps, and magnetic spectrometers. Facility Operations does not include cost of setup and execution of individual experiments, support of in-house research, support of outside user research, or cost of Plant and Capital additions to the accelerator laboratory.

Senator DOMENICI. Senator Ford.

Senator FORD. Thank you, Mr. Chairman, and because of the press of time we are having of a very significant vote at 3 o'clock, I will not be too lengthy. I will have some questions in writing and will submit those to you and that way I will probably get a better understanding. This is a very sensitive and highly sophisticated field and I want to be sure I am not off on the wrong track. So I will submit those questions to you in writing.

But, doctor, there is one significant statement that I have been able to scrutinize in your 72 pages. I have flipped through them and a few neon lights come on and one came on on page 56. I was personally concerned by that page and I see your helpmates back there scrambling through your statement. Beginning on the first sentence on page 56, if you all want to stay with me, I may not be able to pronounce all of these sophisticated words. You say:

> In fiscal year 1985 we intend to mount a research program to investigate how changing the emissions of the SO_2 and NO_x that eventually enter storm clouds might affect the acidic deposition, acid rain, that falls from those clouds. We will be particularly concerned with whether a given reduction in emissions from the source will result in a proportional reduction in rain acidity over ecologically sensitive regions. If successful, the results of this research will have significant implications for the design of effective and economical emission reduction strategies.

What are you planning on doing as it relates to this particular field? I am from a coal producing State and it is obvious that I would be interested in acid rain. I am glad to see that the administration finally has hooked up on wanting to get the cloud off the coal industry where it is being placed very effectively now.

If we remove that cloud with an effective type of strategy, that will economically reduce the problem that we have. Under the strategy as I see it now, my people are giving us the figures, if we go with the bill that emerged from the Public Works and Environmental Protection Committee, it will cost my ratepayers in Kentucky from now on $700 million additional. We are trying to find a solution to it and we do not know what the problem is yet, the basic problem.

Can you tell me a little bit about what you are trying to do in this request for fiscal year 1985 as it leads to help changing the emissions?

Dr. **Trivelpiece**. First, let me say I count myself among those who believe that substantially more scientific data is required before some kind of mitigation strategy is put in place. The cost of mitigation would be very, very large and the damage, if any, has yet to be demonstrated in a way which I think makes the clear scientific cause and effect relationship available.

The National Academy of Sciences conducted a study, and what they said essentially is what goes up comes down. That is kind of a mass conservation statement which has led to this idea that a proportional reduction in the deposition if the source emission is reduced by some amount.

However, that does not take into account the fact that a particular source will have whatever emissions it emits carried into clouds, modified in clouds and deposited in different places, and that changes as a function of the air movement. It also may change as a result of whether or not the chemistry involved is linear or nonlinear in some way; that is what kind of chemical processes are going on.

So we are beginning a program to investigate in a more direct sense where the pollutant comes from, where it goes, and how it gets modified in the meantime. This involves atmospheric modeling and trying to incorporate chemistry and things like that.

In addition, there was an experiment that was started 2 years ago, I guess, called Captex which means cross Appalachian tracer experiment, in which some prefluoro-carbon tracers were released in Ohio and at Sudbury in Canada and then some 80 stations on the ground and 15 airplanes were used to collect air samples at various points over an extended period of time. Now, those samples have been collected and are being analyzed.

What that will do or help to do is identify a connection between a geographic source emitter and a geographic receptor, but without specifiying what happens to the chemistry in between; that is, what happens to the SO_2 and the NO_x as they go from one place to another.

All of these things need to be done. I think more scientific information is needed. You are aware that the Department does have a control technology program started this year, which I think asks for some $26 million increase, if I recall correctly. That involves what can be done at the source in order to reduce the emission and can you do so in a cost effective way, rather than something that would require the kind of mitigation cost that you are talking about.

Senator **Ford**. Doctor, are we looking at ways, are we including ways in the research to have a clean burning coal such as the fluidizied bed combustion and other items that would be used?

Dr. **Trivelpiece**. Yes, sir. There is a process called limestone injection, multistage burners and there are some funds, I believe, in the Environmental Protection Agency's budget this year to pursue some activities there. That approach owes its existence to the kind of research facilities that the department has, such as the Combustion Research Center at Livermore that is operated by the Sandia Laboratory. Some of the early research on this lime injection approach was in fact carried out there.

Senator **Ford**. When you say lime injection, is that the fluidized combustion bed operation?

Dr. **Trivelpiece**. Using limestone as an additive in the combustion process in order to produce chemcially more benign output from the emission process, from the combustion process.

Senator **Ford**. We find it was very hard to go to, I guess, the pilot stage with any kind of help from the Federal Government. We filed a little bill here, say, to $50 million to add on and we finally were able to get $30 million in each of the next 3 years for the joint TVA pilot project that is going on near Paducah. I do not know whether you are aware of that one or not. But we find the State of Kentucky has put up roughly $15 million, the TVA has put up $15 million, Duke Power has put up $15 million, Peabody is putting up $4 or $5 million, EPRI is putting up $75 million. It seems like we are having difficulty in getting some interest as it relates to the clean burning of coal.

This is about 160 megawatts which is a small operation. Put it in round figures, once it gets in place, it will burn 600,000 tons of high sulfur, western Kentucky coal annually. That is just a small operation. You see what it could do for our employment. Coal is our basic resource.

So I am very much interested. I also thought maybe there might be contracting to look at how the emissions travel out of that particular plant. Are you familiar with or aware of anything that is being done in that area?

Dr. **Trivelpiece**. I am not aware of that being part of the programs we are talking about here today.

Senator **Ford**. Others are trying to move into that area. If we can have some kind of cooperation, working together, rather than separately and come up with the same answer maybe.

I was a little bit amused looking at the academy reports on acid rain and EPA came out with a little statement that I thought was significant. It said that they are not so sure but what we need is a little SO_2 in the atmosphere to prevent the so-called greenhouse effect. Do you know how much SO_2 you need in the air to prevent the greenhouse effect? I was a little bit intrigued by that. Are you knowledgeable about what they are trying to say?

Dr. **Trivelpiece**. I understand what they are trying to say. I am not sure whether or not there is a technical connection between those two, but I would be glad to check it out.

[The information follows:]

THE EFFECT OF SO_2 AS A GREENHOUSE GAS

In the troposphere (below about 20 km) SO_2 is an insignificant greenhouse gas (The maximum temperature change one might expect from a doubling of SO_2 concentrations in the troposphere is in the range 0.02–0.95° C). SO_2 becomes a negative greenhouse gas (i.e., could cause cooling) only when atmospheric chemistry converts it to SO_4, a particle, and it is transported to the stratosphere (above 20 km). The particles reflect sun light and act to cool the earth. It is believed that fossil SO_2 is not a significant greenhosue actor, positive or negative, because most fossil SO_2 does not reach the stratosphere.

Senator **FORD**. They said there is a connection and it is hooked up in some way or another. It makes the point that we are not sure of where we are going if we reduce 10 million tons. If we reduce from 1.2 pounds per million Btu's generated to, I believe you have eliminated the western Kentucky coal operation, have you not, roughly 45,000 jobs. Of course, they may move to something else. If you move that down to I believe 0.85, if you move that down to 0.85 and that leaves just 1 percent of all compliance coal reserves in our State, 1 percent, that will be compliance coal. So we are going to have to find some other source to reduce it. That is an energy source we may need at some time, particularly for industry consumption.

Dr. **TRIVELPIECE**. I agree.

Senator **FORD**. I thank you for your answers, doctor. Mr. Chairman, while you were out, I said I will submit several questions to the doctor in writing.

Senator **DOMENICI**. Thank you very much, Senator Ford, I had to go make a call to my State regarding something developing there or I would not have left as I did. Thank you for accommodating me.

Senator Warner, did you have some questions?

Senator **WARNER**. Yes, thank you, Mr. Chairman. Recognizing the Chair's desire to conclude this hearing by 3 o'clock, I will ask that the statement I intended to make be included in the record and I will then proceed to several questions.

Senator **DOMENICI**. That will be made a part of the record.

[The prepared statement of Senator Warner follows:]

STATEMENT OF SENATOR JOHN W. WARNER
March 20, 1984
Senate Subcommittee on Energy Research and Development

The Southeastern Universities Research Association (SURA) is a consortium of 28 universities located in 10 states and the District of Columbia formed for the purposed of managing large cooperative projects in science, engineering and medician. Member universities include:

Virginia:
Norfolk State
George Mason University
University of Virginia
University of Richmond
Virginia Commonwealth University
Virginia State University
College of William and Mary
Hampton Institute
Old Dominion University
Virginia Polytechnic Institute and State University

Maryland:
University of Maryland, College Park

District of Columbia:
American University
Catholic University of America
George Washington University
Georgetown University

North Carolina:

Duke University

University of North Carolina, Chapel Hill

North Carolina State University

South Carolina:

Clemson University

University of South Carolina

Alabama:

University of Alabama, Birmingham

Auburn University

Georgia:

Georgia Institute of Technology

Louisiana:

Louisiana State University, Baton Rouge

Florida:

Florida State University

Florida Institute of Technology

University of Miami

Kentucky:

University of Kentucky

The proposal to develop the Continuous Electron Beam Accelerator Facility (CEBAF) at Newport News, Virginia is the consortium's first project.

The accelerator would be used to investigate properties of the subatomic world of the nucleus of atoms which is destined to become a new frontier of nuclear physics in the coming decade. The so-called "quarks" and "gluons" that make up the protons and neutrons of atoms would be aroused by collisions with high-speed electrons produced by the accelerator. Those energized quarks would then be free to move around in the nucleus, and in so doing, would cause the nucleus to exhibit new properties that could help reveal new secrets of matter.

The intensity (number of particles per second) of the beam in combination with multi-GeV energy and uniquely high duty factor (continuous rather than pulsed beam) will make CEBAF unique in the world.

Although the SURA organization has been in existence for less than four years, SURA member institutions have played a major role for more than a decade in providing the scientific justification that led the U.S. nuclear science community to recommend a 4 GeV electron accelerator. SURA submitted an initial proposal for a 2 GeV electron accelerator with plans for upgrading to 4 GeV to the Department of Energy and the National Science Foundation in 1980, two years before similar proposals were submitted by competing groups.

The Department of Energy/Nuclear Science Foundation's Nuclear Science Advisory Committee (NSAC) has developed a long range plan for basic nuclear research in the U.S. The 1983 Long Range Plan reaffirms NSAC's April 1983 recommendation that construction of a 4 GeV continuous electron beam facility be initiated as soon as possible.

By 1983, five institutions formally submitted proposals to the DOE to develop the accelerator. The DOE and NSF requested that NSAC establish an ad hoc panel to review and evaluate the five proposals and recommend the facility which would best meet the U.S.' needs for basic nuclear research with electromagnetic probes. The "Panel on Electron Accelerator Facilities" was chaired by the distinguished Professor D. Allan Bromley of Yale University.

Following public presentations, site visits, and written critiques, this panel reported its findings to the DOE/NSF Nuclear Science Advisory Committee on April 22 and 23, 1983. In an April 29 letter to DOE and NSF, the Chairman of NSAC transmitted the Panel report with NSAC's full endorsement and recommendation that the report be implemented without delay.

As its principal recommendation, the Panel on Electron Accelerator Facilities recommended "that the proposal submitted by SURA be accepted and funded for the construction of a new accelerator centering on a 4 GeV linear accelerator-stretch ring capable of delivering intense, high duty factor, electron beams in the energy range from 500 to 4000 MeV."

Needless to say, Mr. Chairman, I was extremely pleased that these committees of some of America's most eminent physicists judged the SURA proposal superior to all others submitted. I understand that the technical quality of the design and the ability of SURA to develop the facility were given the greatest importance, but that other factors were considered, such as the impact of the proposed accelerator on graduate education, the ability to attract top, new personnel into nuclear physics, and the creativity and knowledge of the SURA scientists who designed it.

The President of the American Physical Society, Dr. R. E. Marshak, has stated: "... the procedures used by the Bromley Panel were extremely careful and even-handed... The painstaking step-by-step procedures adopted are clearly a model of fairness and responsibility, and I urge that its carefully constructed recommendations be considered with equal care."

The commitment of those of us from the SURA member states to this project is an extremely strong one, as evidenced not only by the interest here in the Congress, but also by the contributions of state and local government and member universities. I want to submit for the record a July 12, 1983 letter to Secretary of Energy Hodel signed by 15 SURA state Senators in support of the project, as well as recent letters from Senator Russell Long and Senator Ernest Hollings confirming their support.

Approximately $1.5 million in State and university dollars have been expended on CEBAF to date. Funds for five Governors' Distinguished CEBAF Professorships, four other senior positions, and eleven junior personnel will be provided by Virginia starting July 1, 1984. Other support brings Virginia's total contribution to more than $1.5 million for the next two years. The support for the nine senior positions and 17 additional state positions is expected to continue for the life of the project.

The SURA universities are committed to provide a total of at least 35 additional tenure stream positions in nuclear physics upon approval of the CEBAF. These positions represent a significant increase in total university involvment in nuclear physics and should yield an increased flow of young highly trained nuclear scientists to provide the manpower needed to address new frontiers in nuclear science and to contribute to the needs of the nation for highly qualified technical manpower.

The U.S. now faces serious international challenges to its economic prosperity and national security, and it is essential that we continue our pursuit of excellence in science and technology. If the Federal government ignores the advice which it sought on the questions of electron accelerators, the scientific community will question the productivity of making available its most highly qualified personnel to participate in objective review processes and recommend the best course of action for the Federal government. The American scientific community certainly understands its international competition; we in Congress should heed their technical judgment.

February 9, the Department of Energy submitted to the Senate Committee on Energy and Natural Resources, as well as the Senate Appropriations Committee, a proposed reprogramming action to transfer $2 million of FY 1984 operating expenses from broadly scoped accelerator research development activities in support of the overall nuclear physics program to accelerator research and development activities in more direct support of CEBAF.

Both the House Science and Technology Committee, as well as the House Appropriations Committee, have cleared the reprogramming request. I encourage my colleagues on this Committee, as well as the Senate Appropriations Committee, to do likewise.

Most of the $2 million will be spent to develop the prototype of those technical components which form a major role in the accelerator design and to fund a core staff. Specific activities in FY 1984 will include:

1) Accelerator design studies into the technology of linear electron accelerators, recirculation of electron beams through an electron linear accelerator for multiple passes of acceleration, pulse stretcher storage rings, electron beam transport instrumentation, and physics research instrumentation;

2) Prototype development of high-powered RF equipment, accelerator structures, and beam injection and extraction instrumentation;

3) Advanced conceptual design;

4) Advanced studies of experimental equipment needed to carry out a program of basic nuclear research with electron beams.

The DOE has stated that, regardless of the future of CEBAF, the FY 1984 activities would be a worthwhile contribution to the nuclear physics program and the nation's overall advancement of important areas of accelerator technology.

I want to emphasize how critical the release of these FY 1984 funds is to CEBAF. SURA does not have the existing manpower and equipment base of the national laboratories. These funds are urgently needed to establish a manpower base, perform technical engineering and design, and maintain the project schedule. The universities and the Commonwealth of Virginia cannot continue indefinitely to finance this project and maintain the momentum necessary to meet the construction schedule.

The President's FY 1985 budget request to the Congress includes $5 million in operating expenses for research and development in support of the CEBAF project. To initiate the CEBAF construction effort, $2 million in construction funds is requested.

I urge my colleagues on this Committee to concur with the Administration's support of CEBAF so this important project can move forward.

Senator **WARNER**. Thank you. The project, that is pending before the Congress now for authorization and your secretary with your wise counseling and advice came forward with a reprogramming action for a very modest sum of money and that is coming before the Senate now. It has been accepted by the House and therefore it is my hope that the Senate can act within the prescribed time, which terminates this week. Consequently, in addition to the questions that I pose today, would you provide the answer to other questions prior to this Thursday, so that we can hopefully get action by the Senate in time for the schedule.

Having said that, I am pleased to see that the education institution in the State of Kentucky has now joined serial group. That rounded out to a quite a few States and universities that are involved in this.

Specifically, what are the unique characteristics of the beam that can be provided by the CEL compared to those of existing accelerators?

Dr. **TRIVELPIECE**. The problem here is trying to understand, not just the atom but the nucleus of the atom and in fact, one of its interior parts, the protron or the neutron. One of the ways by which you can get at these problems is to understand the components that make up the protrons and neutrons, the so-called quarks. It takes various combinations of three quarks to make up these subatomic particles.

The nucleus, as an object, has the characteristic when a high speed electron passes through it, that it shakes it up. It more or less heats it up, you might say. In so doing, the nucleus will then relax back down, if you do not do anything to it. But if you hit it very hard, you eventually reach a state where the nucleus is more like a plasma; it is a fluid.

Instead of being discrete objects with discrete interior parts to them, they then tend to be kind of a mush or a plasma. This moving around of the interior of the nucleus, heating it up in this way provides the opportunity to get some new information. The way you can do that is to have this high current of electrons at high energy strike it.

The problem is that the events that occur are very rare. They do not occur very frequently. So in order to get enough of them to study, you need to have a large number of electrons hit the target per unit time. That is what makes this particular accelerator unique. It is not the 4-gegaelectronvolt energy which it requires that is novel in comparison to current accelerators. It is the electron beam, which requires two hundred one-millionths of an ampere that has to be on continuously and that amounts to a lot of electical power. That electrical power has to be dissipated in the right way and that leads to some technology challenges in the design and construction and operation of the accelerator. That provides some, not difficulties, but provides some challenges for the engineers.

So it is the need to have a large number of events, the need to have a steady current of electrons, and the fact that that translates into a lot of electrical power, which provides some challenge.

Senator **Warner**. The Secretary has made a judgment, and indeed it has been reenforced by the administration through certain budget actions, that the United States needs these continuous beam electron accelerator facilities. What are some of the other reasons why it is so worthy to come to support this project?

Dr. **Trivelpiece**. It is my view and it is the view of the administration as well that we need to try to find a few areas that we can use for training talent, for providing some basis for excellence in research and to try to establish some new partnerships in universities and in industry and so on. I think this is an outstanding example of the kind of facility that provides forefront challenge for the next generation of young scientists. It provides new information that, if past experience is any guide, will certainly be of benefit to the Nation in terms of technology available to our citizens eventually.

I think it is just generally speaking a good investment, because of the knowledge and the excellence and the challenge that it provides.

Senator **Warner**. Given that background, would you explain the need for the reprogramming action which hopefully will occur prior to congressional authorization?

Dr. **Trivelpiece**. The reprogramming action was to do some of the early work at the site in order to be in a position to start the construction and the early research activities at the beginning of fiscal year 1985. This is the kind of information that the Department would normally have generated by this time; there have been some delays in our own internal management activities leading to making this request somewhat later than we had originally planned. But we would like this reprogramming to occur.

Senator **Warner**. It is not unprecedented for the Department of Energy to make such funds available for such projects prior to proceeding with congressional approval, that is the authorization.

Dr. **Trivelpiece**. I want to be careful in the way I say this. We do not start construction projects before they have been authorized and appropriated. Nevertheless, there are preliminary engineering design activities which, for projects the Department proposes in some subsequent year to bring before the Congress, need to be done in order to have an accurate and adequate estimate of the cost, the schedule and the like.

In fact, the Office of Management and Budget will not permit us to bring these things forward without such information. Some expenditures are required to do so.

Senator **Warner**. Mr. Chairman, I would like to thank the witness and I am hopeful that the witness can complete these prior to the end of this week.

Senator **Domenici**. Were you finished, Senator?

Senator **Warner**. Yes.

Senator **Domenici**. Senator Warner will give you those questions right now and if you could answer them as requested, we would appreciate that.

Dr. **Trivelpiece**. Certainly.

Senator **Domenici**. Thank you very much. Your entire statement will be made a part of the record. You are excused. Thank you very much.

Dr. **Trivelpiece**. Thank you, Mr. Chairman.

Senator **Domenici**. Now we have from the Fusion Energy Foundation in New York Marsha Freeman; Robert M. Rosenzweig, president of the Association of American Universities, Washington, DC; Stephen O. Dean, president, Fusion Power Associates, Gaithersburg, MD.

Would you proceed, Marsha Freeman. We are delighted have you and then we will take Mr. Rosenzweig and then Stephen Dean. You may proceed.

STATEMENT OF MARSHA FREEMAN, DIRECTOR, INDUSTRIAL RESEARCH, FUSION ENERGY FOUNDATION

Ms. **Freeman**. Thank you very much, Mr. Chairman, and thank you for this opportunity to testify before the subcommittee today. I would like to make some general points about the fusion program, since that foundation is not involved in particular research, but is a foundation that does a lot of work in promoting the development fusion and gets involved in policy questions about the program.

First, I would like to say that it seems to us that the budget funding request for fusion this year as well as for other research and development programs is being very much determined by the budget climate overall and the question of the Federal deficit. As I go into in some detail in my written statement, it is our judgment inlooking at the effect of research and development spending in the budget that the problem of the deficit should not be something that determines what the funding level for fusion should be.

I would say in general that what makes up the budget deficit, what kind of funding the Government is involved with can either hurt or promote the growth of the economy and I would state, and we have done studies to document this, that if the budget deficit were perhaps caused by larger expenditures in frontier areas in science and research and development, we might see that deficit actually produce economic growth in the future and not have problems with it.

I think that the funding level for fusion and other of the R&D programs has to be seen in terms of the consequences for the future growth of the economy and not just short-term considerations.

Second of all, I would like to pose to you that the fusion research program be looked at in a much broader light than the general perception of the Department of Energy and other people. It is our estimation that the research that is being done in fusion will not only be very critical for a future energy option for producing electricity and industrial heat and other forms of energy, but that fusion research is also very important for our national security at this time.

That is certainly true in energy. It is also true in the development and pushing toward the frontiers in programs such as the President's directed energy beam weapon and defense effort. There has been some preliminary work on this in the Department of Energy. But it is certainly the case that the science developed through the fusion program and the technologies will be very important for the directed energy beam defense program and that is to take a look at the fusion program as having an impact directly on the national security of this country. I think it is a very appropriate path to take.

In addition, I would also state that the research that is done in fusion has potentially many more applications than just simply one of a number of sources of electric power. I would think we would want to look at our fusion laboratories as laboratories for advanced technologies in plasma techniques, superconductant and cryogenic technology and other engineering and technology spinoffs that will be important for the economy as a whole. People who have worked in fusion have gone out of the fusion program with the knowledge and the background they gained working on fusion energy and have gone into other plasma applications in steel making materials and other fields.

So I would say that we have a national resource for national defense for the future growth of the economy and also for many applications in industry, materials, medicine and biology and other fields. So I would really wrap up by saying that I think if the fusion program were looked at from this broader scope and prospective that the funding level would be appropriate to push in all of the frontier areas to make sure that these fields really all benefit from the very fine fusion program that I think we have today.

[The prepared statement of Ms. Freeman follows:]

Statement of Marsha Freeman

Fusion Energy Foundation
New York City

Mr. Chairman and Members of the Subcommittee:

Thank you for this opportunity to present the views of the Fusion Energy Foundation on the FY85 budget request for the Department of Energy Magnetic Fusion Energy program.

The testimony that has been presented before this subcommittee by the Department of Energy proposed a go-slow fusion program that is scientifically incompetant compared to what the fusion program must accomplish.

The frontiers of plasma physics research are of immediate importance for the solution to the world's severe energy deficit; they directly overlap with the most crucial questions of directed energy beam weapon defense and with the frontiers of astrophysics and bioengineering research. The pace and level of fusion funding must be considered within this framework of moving the nation foward in the frontiers of science, for economic growth and national defense.

In the three years since the passage of the Magnetic Fusion Energy Engineering Act of 1980, the Reagan Administration has refused to fulfill the mandate of that law with regard to both the proposed funding profile for fusion and a program plan to meet the milestones laid out by the Congress.

In his testimony representing the view of the Administration before the House subcommittee on Energy Research and Production on Feb. 23, Dr. Alvin Trivelpiece stated that because of the "current climate" where the prices of oil and yellow cake are going down, "it is difficult to make a rational case for accelerating the [fusion] program." Under questioning, Dr. Trivelpiece agreed that the goal of demonstrating the commercial viability of fusion could be accelerated with increased funding, but that high budget deficits make funding increases difficult.

The Administration has continued to try to convince the American people that the so-far invisible economic "recovery" depends upon decreasing the budget deficit. First, it is important to understand that there is no economic recovery. All real production indicators show that basic industry, farming, and manufacturing have been contracting, and that the number of real productive jobs in the economy is shrinking. Only the made-up figures of the Federal Reserve indicate that there is a "recovery."

Second, the simple amount of the federal budget deficit has nothing to do with the state of the economy. The only determining factor is the mix of activities the government is engaging in which are causing the deficit. If the government were using this credit to expand industry, develop new energy and industrial technologies, expand the civilian space program and push forward the laser, particle beam, and plasma technologies required for new defensive antimissile systems, there would be economic growth as a result of the budget deficit. If the millions of currently unemployed Americans were working and paying taxes, budget balancers would not even have a budget deficit to worry about.

Third, the only basis for a real economic recovery is the priority investment in the frontiers of science and technology --fusion and directed energy defensive weapons--for this will ensure a continuing increase in productivity by the introduction of new technology.

Cutting crucial R&D programs, using the excuse that there must be a cutback in government spending, ensures there will be a slowdown in the rate of introduction of new technology into the economy, which is, after all, the driving force of increased productivity and economic growth.

The relationship between the rate of introduction of new technology into basic industry and economic growth was demonstrated in a study done last year by the economic staff of the weekly magazine Executive Intelligence Review and the technical staff of the Fusion Energy Foundation. This groundbreaking study, using the LaRouche-Riemann economic model, showed that a crash program for directed energy beam defense development could add millions of new highly skilled jobs to the U.S. economy, raise per capita income by 5 percent per year, eliminate the trade deficit within two years by gearing up exports, and produce a 25 percent per annum rate of growth in the economy. This effect would be caused by the transfer of technologies developed for the military into the industrial economy.

The potential economic impact from advanced energy technologies such as fusion, is even greater. Fusion research should be seen as a national laboratory for the new industries of the economy. Plasma-based steelmaking, chemistry, materials processing, and even space travel will revolutionize the U.S. economy. The nation's fusion scientists should have the resources to begin now to prepare the technologies of the plasma age.

Regardless of how depressed the electric utility industry may be at the present time, if there were even a modest upturn in economic activity, there would be shortages of on-line electric generating capacity in less than five years. According to the National Electric Reliability Council, certain regions of the country could experience brownouts by 1985. To plan for the future on the basis of the fall in electricity demand for the last two years, is to state categorically that we will be in a depression for years into the future.

The Administration has stressed in its statements on science and technology policy that international cooperation must bail the United States out of tight R&D budgets. It has even been suggested that national sovereignty might have to be compromised as other nations are encourgaed to build the fusion facilities and perhaps other facilities that the U.S. niggardly refuses to spend the money on.

Rather than taking on the responsibility that the United States has, as the world leader in science and technology, to lead the international effort in fusion, Administration officials are questioning whether or not to relinquish that role.

Little consideration has been given to the fact that the frontier scientific questions in fusion are also crucial for national defense. The defensive technology thrust announced by President Reagan last March 23 will require creative input from fusion scientists. As Dr. Edward Teller has stated, it is time for the fission and fusion communities to reunite to tackle and solve these challenging problems, to protect this nation and allies from nuclear attack. We cannot slow down fusion research and development without effecting national defense.

For these economic and military reasons, the U.S. fusion effort must be "technology limited" and not "funding limited." The funding profile that was the foundation for the Fusion Act four years ago, has still not been achieved today. The FY85 budget request from the Department of Energy is still below the $500 million mark that was deemed necessary at the beginning of 1980.

The funding level for the magnetic fusion program should be determined by how quickly money could be absorbed for the design, construction, and operation of the Tokamak Fusion Core Experiment; the continued use and upgrade of other facilities and experiments; and the expansion of physics research which will provide new ideas on better fusion machines in the future.

There must be room in the budget to investigate the possibility of using polarized fuels to relax the classicial parameters for fusion ignition. Promising concepts, such as the plasma focus, which have had to rely on other government agencies for support, should be brought directly into the fusion program. And serious attention should be given to the role that our fusion program must play in the directed energy beam defense effort.

Any society which develops policies based on the notion that science and technology programs are a luxury which the country may not be able to "afford," or that these programs will bring to fruition a technology that "we do not need right now" has lost any sense of history and certainly any vision for the future.

I would be pleased to answer any questions. Thank you.

The Fusion Energy Foundation is a non-profit organization with over 15,000 members in the United States, and is the publisher of FUSION Magazine. FUSION Magazine, which is published in six languages, has a circulation of over 250,000, and has played an important role in helping to forumlate fusion policy for the past decade.

Marsha Freeman is the Washington editor of FUSION magazine, and the Director of Industrial Research for the Fusion Energy Foundation.

Senator **Domenici**. Thank you very much. We will make your statement as you delivered it a part of the record.

Ms. **Freeman**. Thank you.

Senator **Domenici**. We will proceed now with the president of the Association of American Universities, Robert M. Rosenzweig. We have your statement and we will make it a part of the record. You may proceed.

STATEMENT OF ROBERT M. ROSENZWEIG, PRESIDENT, ASSOCIATION OF AMERICAN UNIVERSITIES

Mr. **Rosenzweig**. Thank you, Mr. Chairman. I appreciate the invitation to be here and I should say I am appearing here in addition on behalf of the Association of American Universities on behalf of the American Council on Education, the Land-Grant and State Universities Association and the Council of Graduate Schools.

Rather than rehash the comments in my detailed statement, I would like to focus briefly on two overarching issues that seem to us to be worth separate consideration. The first of those issues might be called the investment strategy for university research. The burden of my remarks on this point is simple, we desperately need one and we do not right now have one. To put the matter simply, the history of scientific support from Government can be divided roughly into two periods. The first period ran from about 1950 until about 1970 and it was marked by rapidly rising research support budgets from a variety of Federal agencies, accompanied by programs whose purpose was to build the Nation's capacity to do basic research.

Universities during that period had access on a competitive basis to money for facilities, instruments and graduate student support. Thus, as society was making demands on the system to produce the results of research, the Government was also providing the capital to make that possible.

In the late 1960's that strategy changed and since about 1970, Government policy can be described as one of attempting to buy the product of an apparatus that had already been created without continuing to make the investments required to keep the apparatus working in top form. We have actually become all too familiar with that policy in this country, because it is the policy that has governed strategy in most of American heavy industry.

We are paying the price for it in its industrial manifestation and we are about to begin paying a price for it in research. Without the needed capital investment, research will continue to be performed as steel and autos continue to be produced, but its quality will diminish; it will become more expensive, if only because the return from it wil be lower and it will become less competitive in the world market.

The budget of the Department makes an encouraging start toward remedying, toward a different strategy, particularly in the area of instrumentation. We believe that the funds are also required for fellowships and for facilities as well. And we hope if not in this year, then in forthcoming years funds will be made available for those purposes.

The second matter I want to bring to your attention has to do with facilities as well. Although it has broad implications for the whole of science, I have brought for submission in the record a set of statements issued within the last 6 months by virtually all of the major organizations of universities and of scientific societies. In different words, they all say the same thing; namely, that the only public policy that can assure that the public's money will produce the best science is one in which decisions about who shall do what science are made by competent professionals judging proposals in fair competition.

That view of the matter is quite universally subscribed to with respect to individual research projects. We have to understand, the Congress not least of all, that second-rate science is of limited value and that the people who are most likely to recognize first-rate science are first-rate scientists.

However, the long drought in the funding of research facilities has led some to the view that the standards of judgement that apply to decisions about scientific facilities are different from the standards that apply to scientific projects. They are not. The most important judgment about a proposed scientific building has to do with the quality of the science that will take place within it. That decision is best made by good scientists.

The answer to the problem is to make funds available for which institutions can compete on the basis of the quality of their programs. Until that happens, and I hope that will be soon, we risk serious damage to the structure that has produced the finest basic science in the world if we allow short-term political considerations to govern scientific decisions.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Rosenzweig follows:]

STATEMENT OF ROBERT M. ROSENZWEIG, PRESIDENT, ASSOCIATION OF AMERICAN UNIVERSITIES ALSO ON BEHALF OF THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE, MY NAME IS ROBERT M. ROSENZWEIG AND I AM PRESIDENT OF THE ASSOCIATION OF AMERICAN UNIVERSITIES. I SUBMIT THIS TESTIMONY IN BEHALF OF THE MEMBERSHIP OF THE ASSOCIATION OF AMERICAN UNIVERSITIES AND THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES WHICH TOGETHER REPRESENT 170 OF THE NATION'S UNIVERSITIES AND COLLEGES WHICH CARRY OUT RESEARCH SUPPORTED BY THE DEPARTMENT OF ENERGY. THEY ALSO TRAIN ALMOST ALL OF THE RESEARCH SCIENTISTS WHO CARRY ON BASIC AND APPLIED RESEARCH ACTIVITIES, NOT ONLY AT AMERICAN UNIVERSITIES BUT THROUGHOUT AMERICAN INDUSTRY. AS SUCH, THEY TOGETHER COMPRISE THE ACADEMIC BASE FOR MOST OF THE DEPARTMENT OF ENERGY'S RESEARCH AND TRAINING PROGRAMS. I WOULD LIKE TO PRESENT TO YOU OUR VIEWS WITH REGARD TO THE FY 1985 BUDGET REQUEST FOR DOE UNIVERSITY RESEARCH AND RELATED PROGRAMS BY FIRST ADDRESSING SOME GENERAL CONCERNS AND THEN DISCUSSING THEM IN THE CONTEXT OF THE DOE BUDGET.

GENERAL DISCUSSION

ALL OF OUR NATIONAL POLICY OBJECTIVES DEPEND HEAVILY ON GRADUATE EDUCATION, BOTH FOR HIGHLY TRAINED PERSONNEL AND FOR ADVANCES IN SCIENTIFIC AND TECHNICAL KNOWLEDGE THAT SUSTAIN OUR ECONOMY AND ENSURE OUR DEFENSE. IT IS OUR GRADUATE SCHOOLS WHICH PROVIDE THE CONTINUING SUPPLY OF TALENTED INDIVIDUALS WITH THE KNOWLEDGE, TECHNICAL SKILLS AND PERCEPTION WHICH EQUIPS THEM TO MEET THE CHALLENGES OF THIS COMPLEX AND AND TECHNOLOGICALLY SOPHISTICATED AGE.

WE CAN LOOK AT OUR NATION'S MODERN HISTORY FOR EVIDENCE OF THIS. DURING WORLD WAR II, THERE WAS AN EMPHASIS ON FEDERAL SUPPORT FOR UNIVERSITY PROGRAMS FOR RESEARCH AND GRADUATE TRAINING WHEN THERE WAS A SUDDEN DEPENDENCY ON UNIVERSITY-BASED SCIENCE AND SCIENTISTS. AND AGAIN, IN THE LATE 1950S, AFTER THE SUCCESSFUL LAUNCHING OF SPUTNIK, THERE WAS AN INCREASED FEDERAL INTEREST AND INVESTMENT IN RESEARCH AND ADVANCED EDUCATION AS PARTS OF A GREATER NATIONAL EFFORT TO REGAIN AND SUSTAIN AMERICAN SCIENTIFIC AND TECHNOLOGICAL SUPERIORITY.

THIS LED TO A CLEAR FEDERAL COMMITMENT TO EXCELLENCE IN HIGHER EDUCATION AND RESEARCH. THIS MANIFESTED ITSELF IN THE MANY PROGRAMS OF THE NATIONAL SCIENCE FOUNDATION AND THE MISSION AGENCIES, INCLUDING NASA AND THE DOD, WHICH CONTRIBUTED TO STRENGTHENING OUR RESEARCH AND GRADUATE EDUCATION ENTERPRISE.

SINCE THAT TIME, THE FEDERAL GOVERNMENT HAS REMAINED THE PRIMARY PATRON OF SCIENCE. HOWEVER, ITS INVESTMENT IN THOSE CORE PROGRAMS DESIGNED TO STRENGTHEN GRADUATE EDUCATION AND CONTRIBUTE TO THE RESEARCH AND EDUCATION ENVIRONMENT IN UNIVERSITIES HAS DIMINISHED SIGNIFICANTLY IN SOME IMPORTANT AREAS.

THE DEPARTMENT OF ENERGY FY 1985 BUDGET REQUEST PROPOSES A 24% INCREASE FOR BASIC ENERGY SCIENCES (+$82.2 MILLION) AND A 16% INCREASE FOR GENERAL SCIENCE (+$104.8 MILLION). THIS REPRESENTS A STRONGER COMMITMENT, AND WE HOPE IT WILL BE A SUSTAINED COMMITMENT, BY DOE TO ITS VITAL, BUT OFTEN NEGLECTED, FUNDAMENTAL RESEARCH PROGRAMS. THE UNIVERSITY PLAYS A UNIQUE AND ESSENTIAL ROLE IN THE DEPARTMENT'S RESEARCH EFFORT AND ITS CONTINUED HEALTH REQUIRES A SUSTAINED NATIONAL INVESTMENT.

TODAY MANY OF OUR LEADING GRADUATE SCHOOLS ARE SEEING GRADUATE ENROLLMENTS TUMBLE AS UNDERGRADUATE STUDENTS CLAMOR FOR THE LIMITED SPACES AVAILABLE IN OUR SCHOOLS OF ENGINEERING AND COMPUTER SCIENCE. THE QUALITY OF INSTRUCTION IS BEING THREATENED. FACULTY ARE STRAINED TO MEET THE DEMAND, OFTEN WITHOUT ADEQUATE ASSISTANCE. MORE WORRISOME IS THE AWARENESS THAT THE RANKS OF TRULY TALENTED YOUNG FACULTY COMING ALONG BEHIND THEM ARE THINNING. TIME TO PURSUE RESEARCH FREQUENTLY IS SQUEEZED, AND THE QUESTIONS RESEARCHERS ARE ABLE TO PURSUE IN THEIR INVESTIGATIONS OFTEN ARE CIRCUMSCRIBED BY THE OBSOLETE INSTRUMENTS AVAILABLE TO THEM. THE CAPACITY OF FACULTY TO SUBSTITUTE INGENUITY FOR MODERN RESEARCH TOOLS IS DIMINISHING IN MANY LABORATORIES. IN ADDITION, MANY LABORATORIES ARE AGED; THEY REQUIRE MODERNIZATION IF THEY ARE TO SERVE THROUGH THE DECADE AS EFFECTIVE SITES FOR THE CONDUCT OF MODERN RESEARCH. BUT, DESPITE ALL OF THIS, IT IS TRUE THAT EXCELLENT RESEARCH AND QUALITY EDUCATION PROGRAMS DO CONTINUE IN MANY LABORATORIES. MANY OF THOSE CLOSEST TO THE SCENE KNOW, HOWEVER, THAT INCREASINGLY SERIOUS PROBLEMS DO PLAGUE OUR RESEARCH ENTERPRISE, PROBLEMS THAT, LEFT UNADDRESSED, WILL COMPROMISE OUR FUTURE.

RECENTLY, THERE HAS BEEN RECOGNITION IN MANY SECTORS INCLUDING THE CONGRESS THAT INDEED THE QUALITY OF THE ENVIRONMENT FOR ACADEMIC SCIENCE AND GRADUATE EDUCATION HAS SUFFERED PROLONGED EROSION. TWENTY MEMBERS OF THE SENATE ARE COSPONSORS OF THE UNIVERSITY RESEARCH CAPACITY RESTORATION ACT OF 1983 (S.1537), WHICH WAS INTRODUCED IN THE SENATE LAST YEAR. THAT BILL SETS AN AGENDA FOR A FIVE-YEAR PROGRAM OF INCREASED FEDERAL SUPPORT IN THE SIX MAJOR RESEARCH AGENCIES: (1) TO AUGMENT AND STRENGTHEN FEDERAL SUPPORT FOR FUNDAMENTAL RESEARCH PROGRAMS IN BASIC SCIENCE AND ENGINEERING AT THE NATION'S UNIVERSITIES; (2) TO UPGRADE AND REPLACE THE INSTRUMENTATION AND EQUIPMENT OF UNIVERSITY RESEARCH FACILITIES AND LABORATORIES; (3) TO PROVIDE INCREASED NUMBERS OF GRADUATE FELLOWSHIP AWARDS TO INDIVIDUALS AND UNIVERSITY DEPARTMENTS ENGAGED IN FEDERALLY SUPPORTED RESEARCH; (4) TO SUPPORT EXPANDED FACULTY DEVELOPMENT PROGRAMS THAT PROMOTE THE INITIATION OF RESEARCH CAREERS BY YOUNG UNIVERSITY FACULTY; (5) TO SUPPORT EFFORTS, ON A MATCHING BASIS WITH THE INSTITUTION INVOLVED, TO REHABILITATE, REPLACE OR OTHERWISE IMPROVE THE QUALITY OF EXISTING UNIVERSITY RESEARCH FACILITIES AND LABORATORIES IN WHICH FEDERALLY SUPPORTED SCIENCE AND ENGINEERING RESEARCH IS CARRIED OUT; (6) TO MODERNIZE AND IMPROVE UNDERGRADUATE SCIENCE AND ENGINEERING INSTRUCTIONAL PROGRAMS AND CURRICULA TO MEET THE NATION'S CHANGING NEEDS.

WE CONGRATULATE THE SPONSORS OF THIS LEGISLATION AND ASK THAT THIS COMMITTEE SERIOUSLY CONSIDER THE PROPOSALS CONTAINED THEREIN.

I WOULD LIKE TO ADDRESS FIVE AREAS WHICH ARE APPROPRIATELY CONSIDERED IN THE CONTEXT OF THE FY 1985 DOE BUDGET REQUEST: BASIC ENERGY SCIENCE RESEARCH PROGRAMS, GRADUATE STUDENT SUPPORT, CAREER ENHANCEMENT INITIATIVES FOR YOUNG FACULTY, RESEARCH INSTRUMENTATION AND RESEARCH FACILITIES.

BASIC RESEARCH PROGRAMS

THE PROPOSED BUDGET FOR BASIC ENERGY SCIENCES IS $82.2 MILLION (24%) HIGHER THAN THE CURRENT LEVEL. THIS BUDGET WILL PROVIDE NEEDED CONTINUITY FOR THE VARIOUS SCIENCE PROGRAMS INCLUDING A SIGNIFICANTLY ENHANCED MATERIALS SCIENCES PROGRAM. IT WILL ALSO FUND A NEW EFFORT BY THE DEPARTMENT TO PROVIDE ACCESS TO SUPERCOMPUTERS FOR RESEARCHERS. THE PROPOSED GENERAL SCIENCE BUDGET IS $104.8 MILLION (16%) HIGHER THAN THE CURRENT LEVEL. THESE PROGRAMS SUPPORT IMPORTANT LONG-TERM BASIC SCIENCE RESEARCH IN THE AREAS OF HIGH ENERGY PHYSICS AND NUCLEAR PHYSICS. THE BUDGET ALSO WILL PROVIDE ESSENTIAL SUPPORT TO MODERNIZE SEVERAL ACCELERATORS AND RESEARCH PROJECTS.

WE COMMEND THESE PROPOSED INCREASES. IN RECENT TESTIMONY ON THE FY 1985 DOE BUDGET REQUEST BEFORE THE HOUSE APPROPRIATIONS SUBCOMMITTEE, DR. ALVIN W. TRIVELPIECE STRESSED THAT THESE RESEARCH PROGRAMS OFTEN INVOLVE THE TRAINING OF GRADUATE STUDENTS AT UNIVERSITIES THAT HAVE MADE SIGNIFICANT CONTRIBUTIONS TO THE ECONOMIC GROWTH AND PROSPERITY OF THE NATION. IT IS PRECISELY FOR THIS REASON THAT WE ASK THE COMMITTEE TO AUTHORIZE AN ADDITIONAL $20 MILLION FOR THE BASIC ENERGY SCIENCES PROGRAMS AT UNIVERSITIES FOR INVESTIGATOR-INITIATED FUNDAMENTAL RESEARCH.

GRADUATE EDUCATION

IN 1968, 51,000 FEDERALLY FUNDED FELLOWSHIPS WERE AWARDED. TODAY FEWER THAN 10,000 ARE AWARDED AND OF THESE, ONLY 1,500 ARE AWARDED TO STUDENTS IN ADVANCED STUDY IN THE SCIENCES AND ENGINEERING. DOE AWARDS ONLY ABOUT 25 SUCH FELLOWSHIPS IN NARROWLY DEFINED FIELDS. WE UNDERSTAND THAT THE DEPARTMENT OF ENERGY ATTEMPTED AGAIN TO IMPLEMENT A GRADUATE FELLOWSHIP PROGRAM FOR FY 1985, BUT IT REPORTEDLY WAS NOT SUPPORTED BY THE OFFICE OF MANAGEMENT AND BUDGET. IT IS UNFORTUNATE THAT THIS ATTEMPT HAS FAILED. WE BELIEVE THAT THE DOE SHOULD ATTEMPT TO STRENGTHEN ITS COMMITMENT TO GRADUATE EDUCATION AND WE URGE YOU TO CONSIDER THE NEED FOR A DOE GRADUATE FELLOWSHIP PROGRAM.

THE BEST APPROACH, WE RESPECTFULLY SUGGEST, WOULD BE A TWO-PART PROGRAM, EACH FUNDED AT $2.5 MILLION, TO PROVIDE FOR (1) MERIT-BASED, PORTABLE, THREE-YEAR GRADUATE AWARDS TO STUDENTS AND (2) A COMPARABLE NUMBER OF AWARDS TO DEPARTMENTS THAT CARRY OUT DOE-FUNDED BASIC RESEARCH PROGRAMS. THE POSITIVE IMPLICATIONS FOR THE HEALTH OF SCIENCE AND ENGINEERING DEPARTMENTS DOING ENERGY-RELATED RESEARCH WOULD BE VERY GREAT, WHILE SIGNIFICANT

NUMBERS OF STUDENTS WOULD BE ASSISTED TOWARD COMPLETING THEIR STUDIES. BOTH THE NATIONAL SCIENCE FOUNDATION AND THE DOD'S OFFICE OF NAVAL RESEARCH HAVE STRONG MERIT-BASED, PORTABLE GRADUATE FELLOWSHIP PROGRAMS IN PLACE. THE ONR GRADUATE FELLOWSHIP PROGRAM IS THE PRESENT MODEL FOR EXCELLENCE. IT PROVIDES A STIPEND OF $13,000, FULL TUITION, PLUS $12,000 RESEARCH AWARD TO THE HOST DEPARTMENT. WE RECOMMEND THAT DOE IMPLEMENT A PROGRAM FASHIONED AFTER IT.

YOUNG FACULTY

INCREASINGLY SERIOUS CHALLENGES FACE YOUNG RESEARCHERS WHO SEEK TO BEGIN CAREERS IN BASIC SCIENCE. YOUNG PH.D.S WHO COMPLETE THEIR FORMAL TRAINING AND ASPIRE TO ACADEMIC CAREERS FACE HURDLES MORE SERIOUS THAN THOSE THEIR FACULTY MENTORS ENCOUNTERED. THE ATTRACTIVENESS OF AN ACADEMIC CAREER IS DIMINISHED AND THE PROSPECTS FOR A SUCCESSFUL START NEED ENHANCING.

THE 1982 AAU REPORT TO NSF, "THE SCIENTIFIC INSTRUMENTATION NEEDS OF RESEARCH UNIVERSITIES," PROVIDES A STRIKING EXAMPLE OF THE INCREASED COSTS YOUNG RESEARCHERS FACE AS THEY SEEK TO ESTABLISH THEIR RESEARCH PROGRAMS. THE DATA NOW ARE SOMEWHAT DATED, SO THE MESSAGE THEY CONVEY SHOULD BE INTERPRETED AS A CONSERVATIVE ESTIMATE OF THE PRESENT COST. IN THE CASE OF A LEADING CHEMISTRY DEPARTMENT THE COSTS ASSOCIATED WITH EQUIPPING A NEW FACULTY MEMBER TO DO UP-TO-DATE RESEARCH IN THE FIELD OF SYNTHETIC ORGANIC CHEMISTRY INCREASED FROM $116,500 IN 1970 TO $741,000 IN 1979. INFLATION ACCOUNTS ONLY FOR PART OF THE RISING COSTS. IMPOSED ON THE RISING BASELINE OF INFLATION ARE THE MUCH LARGER COSTS RESULTING FROM ADVANCES IN EXISTING INSTRUMENTATION AND THE DEVELOPMENT OF TOTALLY NEW, MORE POWERFUL, AND, THEREFORE, MORE PRODUCTIVE INSTRUMENTS. YOUNG RESEARCHERS OF PROMISE, BUT WHO ARE YET WITHOUT SUCCESSFUL TRACK RECORDS, CANNOT MEET THESE COSTS WITHOUT SUBSTANTIAL ASSISTANCE FROM THEIR DEPARTMENTS AND INSTITUTIONS; AND THEY ARE INCREASINGLY HAMPERED IN BEING ABLE TO RESPOND.

THE NATIONAL SCIENCE FOUNDATION HAS INSTITUTED A NEW PROGRAM TO PROVIDE RECENT PH.D.S WITH FIVE-YEAR AWARDS AVERAGING $30,000 TO BE MATCHED BY PRIVATE SOURCES. THESE AWARDS WOULD ENABLE THE YOUNG FACULTY MEMBER TO BEGIN RESEARCH IMMEDIATELY, WITH AN OPPORTUNITY TO DEVELOP SKILLS IN THE EARLY YEARS OF HIS CAREER. FOR SOME, IT WILL MEAN THE DIFFERENCE BETWEEN REMAINING IN THE ACADEMIC ENVIRONMENT AND LEAVING TO PURSUE MORE ENCOURAGING AND FRUITFUL ALTERNATIVES.

THE DEPARTMENT OF ENERGY SHOULD BE ENCOURAGED TO START A COMPARABLE PROGRAM TARGETED ON ENHANCING THE HUMAN RESOURCE POOL IN ENERGY-RELATED FIELDS. AN INITIAL INVESTMENT OF $5 MILLION WOULD START THIS INITIATIVE IN FY 1985.

RESEARCH INSTRUMENTATION

THE BUDGET REQUESTS $6 MILLION TO CONTINUE THE ESSENTIAL EFFORT TO UPGRADE UNIVERSITY RESEARCH INSTRUMENTATION AND EQUIP-

MENT, STARTED BY DOE IN THE CURRENT FISCAL YEAR (FY 1984) AT $4 MILLION. WE COMMEND THE DEPARTMENT FOR DOING ITS PART TO ADDRESS THE NEEDS OF OBSOLETE UNIVERSITY RESEARCH INSTRUMENTATION AND WE FULLY SUPPORT THE EFFORT. WE ENCOURAGE THE COMMITTEE AT A MINIMUM TO SUPPORT DOE'S PROGRAM FOR UNIVERSITY RESEARCH INSTRUMENTATION IN FY 1985. BEYOND THAT WE ASK THAT THE AUTHORIZATION FOR THIS PROGRAM BE REVISED BY $24 MILLION, TO $30 MILLION PER YEAR. THIS WOULD FUND THE EFFORT AT A LEVEL EQUAL TO DOD'S RESEARCH INSTRUMENTATION PROGRAM.

I SHOULD LIKE ALSO TO TAKE THIS OPPORTUNITY TO TELL YOU ABOUT A NEW RESEARCH PROJECT, NOW BEING UNDERTAKEN BY THREE HIGHER EDUCATION ASSOCIATIONS WITH THE SUPPORT OF NSF, DOE, AND SEVERAL OTHER AGENCIES, TO EXPLORE ALTERNATIVE SOLUTIONS TO THE EQUIPMENT PROBLEM. THE PROJECT IS SEEKING TO IDENTIFY AND TO EVALUATE NEW APPROACHES TO ACQUIRING, MANAGING, AND USING EQUIPMENT AND TO INFORM THE UNIVERSITY COMMUNITY AND OTHERS OF THE RESULTS OF THESE EVALUATIONS. IT IS A JOINT UNDERTAKING OF THE AAU, THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES (NASULGC), AND THE COUNCIL ON GOVERNMENTAL RELATIONS (COGR). THE PROJECT IS BEING SUPPORTED JOINTLY BY THE DEPARTMENT OF ENERGY, NSF, NIH, DOD, USDA, AND NASA. THE RESEARCH CORPORATION ALSO HAS MADE A CONTRIBUTION. THE EFFORT IS BEING CARRIED OUT UNDER THE GUIDANCE OF AN EIGHT-MEMBER STEERING COMMITTEE DRAWN FROM UNIVERSITIES, INDUSTRY, AND THE NATIONAL LABORATORIES. A LIST OF STEERING COMMITTEE MEMBERS IS ATTACHED (ATTACHMENT A).

THE PROJECT GROWS OUT OF A 1980 AAU REPORT NSF TITLED THE RESEARCH INSTRUMENTATION NEEDS OF UNIVERSITIES. THAT REPORT DOCUMENTED THE DIMENSIONS OF THE EQUIPMENT PROBLEM IN 15 LEADING UNIVERSITIES BY COMPARING THEIR RESEARCH EQUIPMENT HOLDINGS WITH THE EQUIPMENT USED IN A NUMBER OF LEADING COMMERCIAL LABORATORIES AND MAJOR NATIONAL LABORATORIES. AS SHOWN ON THE ATTACHED GRAPH (ATTACHMENT E), THE MEDIAN AGE OF THE EQUIPMENT IN THE UNIVERSITIES WAS FOUND TO BE TWICE THAT OF EQUIPMENT IN THE COMMERCIAL LABORATORIES. THE EXECUTIVE SUMMARY OF THE REPORT IS ATTACHED TO MY STATEMENT (ATTACHMENT C). THE COMPLETE REPORT WAS SUBMITTED TO THE COMMITTEE IN AN EARLIER HEARING.

AS NEW INVESTMENTS IN RESEARCH EQUIPMENT ARE MADE BY DOE AND BY OTHER AGENCIES, WE ALSO MUST EXPLORE FOR NEW APPROACHES TO HELP ENSURE THAT OUR INVESTMENTS YIELD THE MAXIMUM SCIENTIFIC AND TECHNOLOGICAL RETURN.

RECOGNIZING THIS FACT, THE NATIONAL SCIENCE FOUNDATION ASKED AAU, NASULGC, AND COGR TO CONVENE AN AD HOC PLANNING COMMITTEE TO CONSIDER WHETHER A SPECIAL EFFORT WAS NEEDED TO EXPLORE WAYS TO IMPROVE THE ACQUISITION, MANAGEMENT, OPERATION, AND MAINTENANCE OF EQUIPMENT. THE GROUP IDENTIFIED THE FOLLOWING QUESTIONS:

1. DOES SO-CALLED DEBT OR CREATIVE FINANCING HOLD SIGNIFICANT UNTAPPED POTENTIAL FOR UNIVERSITIES AS A MEANS OF FINANCING NEW RESEARCH EQUIPMENT?

2. WHAT MORE CAN UNIVERSITIES DO TO IMPROVE THE WAY THEY ACQUIRE, MANAGE, AND USE RESEARCH EQUIPMENT?
3. CAN INNOVATIONS MADE BY GOVERNMENT AND COMMERCIAL LABORATORIES BE IDENTIFIED AND ADAPTED FOR USE BY UNIVERSITIES?
4. ARE THERE REGULATORY AND POLICY BARRIERS IN UNIVERSITIES OR THE STATES THAT CAN BE IDENTIFIED AND STEPS THAT CAN BE TAKEN TO REMOVE OR REDUCE THEM?
5. CAN PRESENT TAX INCENTIVES FOR THE DONATION OF RESEARCH EQUIPMENT BE IMPROVED TO INCREASE SUPPORT FROM INDUSTRY?
6. ARE THERE CHANGES THAT OUGHT TO BE MADE IN FEDERAL REGULATIONS THAT WOULD EASE THE SITUATION?
7. ARE THERE ALTERNATIVE METHODS OF DIRECT FEDERAL FUNDING THAT WOULD YIELD A BETTER RETURN ON FEDERAL INVESTMENT?

PHASE I

THE PROJECT BEGAN LAST NOVEMBER. IT IS SCHEDULED TO BE COMPLETED IN FEBRUARY, 1985. THE WORK IS PLANNED IN THREE PHASES. DURING PHASE I ANALYSES WILL BE CONDUCTED IN SIX AREAS:

1. THE FIRST IS THE ROLE OF DEBT FINANCING OF RESEARCH EQUIPMENT IN SOUND UNIVERSITY FINANCIAL PRACTICE.

   CONSIDERABLE ATTENTION IS BEING PAID IN SOME PARTS OF THE RESEARCH COMMUNITY TO DEVELOPING NEW, CREATIVE MODES OF FINANCING THE ACQUISITION OF UNIVERSITY RESEARCH EQUIPMENT. THE POTENTIAL USEFULNESS OF SUCH APPROACHES IS BEING DEBATED INTENSELY, BUT THE TECHNIQUES THEMSELVES OFTEN ARE NOT WELL UNDERSTOOD, AND EXPERIENCE IN THEIR USE VARIES CONSIDERABLY. THIS ANALYSIS WILL IDENTIFY THE VARIOUS METHODS OF DEBT FINANCING. IT WILL ASSESS THE DESIRABILITY OF ENCOURAGING DEEPER INVOLVEMENT BY UNIVERSITIES IN THEIR USE, GIVE THE PROS AND CONS OF DIFFERENT FINANCING APPROACHES, AND PROVIDE EXAMPLES OF WHAT HAS WORKED, WHERE THESE TECHNIQUES HAVE WORKED AND WHY. THE ANALYSIS ALSO WILL OFFER SUGGESTIONS TO HELP INSTITUTIONS EVALUATE THE APPROPRIATENESS OF THESE APPROACHES IN THE LIGHT OF THEIR PARTICULAR CIRCUMSTANCES.

2. THE PROCUREMENT, MANAGEMENT, AND USE OF RESEARCH EQUIPMENT IS THE SUBJECT OF THE SECOND ANALYSIS.

OPPORTUNITIES TO STRENGTHEN THE ORGANIZATION AND MANAGEMENT OF UNIVERSITY LABORATORIES AND SUPPORTING SERVICES WILL BE IDENTIFIED AND ASSESSED BY THE SECOND ANALYSIS. PARTICULAR ATTENTION WILL BE PAID TO NEW METHODS OF SHARING EQUIPMENT AMONG DEPARTMENTS AND UNIVERSITIES. THIS ANALYSIS WILL IDENTIFY BARRIERS TO SHARING INHERENT IN THE NATURE OF UNIVERSITY RESEARCH AND WILL CONSIDER POSSIBLE WAYS TO LOWER SUCH BARRIERS. RECENT EXPERIENCE IN USING ADVANCED TECHNOLOGY TO PROVIDE REMOTE ACCESS TO HIGH-COST EQUIPMENT WILL ALSO BE EXAMINED. FINALLY, THE MANAGEMENT PRACTICES OF SELECTED COMMERCIAL AND GOVERNMENT LABORATORIES WILL BE REVIEWED TO SEEK APPROACHES THAT MIGHT BE ADAPTED TO THE UNIVERSITY SETTING.

3. THE THIRD ANALYSIS WILL ASSESS TAX INCENTIVES FOR THE DONATION OF EQUIPMENT AND SUGGEST WAYS TO INCREASE SUPPORT FROM THE PRIVATE SECTOR.

   THE ECONOMIC RECOVERY TAX ACT OF 1981 PROVIDED NEW INCENTIVES DESIGNED TO STIMULATE DONATIONS OF EQUIPMENT TO UNIVERSITIES BY INDUSTRY. EXPERIENCE TO DATE SEEMS TO INDICATE THAT THIS PROVISION IS HAVING A SIGNIFICANT AND BENEFICIAL IMPACT ON THE PROBLEM. THIS ANALYSIS WILL EVALUATE THE EXPERIENCE TO DATE AND ASSESS OPPORTUNITIES TO STRENGTHEN FURTHER THIS NEW INCENTIVE TO CORPORATE SUPPORT.

4. REDUCTION OF REGULATORY AND POLICY BARRIERS IN STATES AND UNIVERSITIES IS THE SUBJECT OF THE FOURTH ANALYSIS.

   A SELECTED NUMBER OF STATE GOVERNMENTS AND UNIVERSITIES WILL BE SURVEYED TO DETERMINE WHETHER THERE ARE POLICY AND REGULATORY BARRIERS TO IMPROVED ACQUISITION, MANAGEMENT, AND USE OF RESEARCH EQUIPMENT. PARTICULAR ATTENTION WILL BE GIVEN TO PROVISIONS IN STATE CONSTITUTIONS AND LAWS WHICH MAY RESTRICT UNIVERSITY EFFORTS TO IMPROVE THEIR RESEARCH LABORATORIES. SOME STATES, FOR EXAMPLE, HAVE LAWS THAT INHIBIT GREATER USE OF CREATIVE FINANCING TECHNIQUES BY UNIVERSITIES. THIS IS A VERY COMPLEX AND DIFFICULT ARENA. BUT WE DO HOPE TO IDENTIFY SUCH BARRIERS AND TO FORMULATE PROPOSALS FOR IMPROVEMENTS OR CHANGES THAT MIGHT BE CONSIDERED BY STATE GOVERNMENTS AND THEIR PUBLIC UNIVERSITIES.

5. IN THE FIFTH ANALYSIS FEDERAL REGULATIONS GOVERNING THE ACQUISITION, MANAGEMENT, AND USE OF EQUIPMENT WILL BE REVIEWED.

   RECOMMENDATIONS WILL BE MADE FOR CHANGES TO CURRENT REGULATIONS THAT WOULD FACILITATE EQUIPMENT

ACQUISITION, ACHIEVE MANAGEMENT IMPROVEMENTS, AND EASE BURDENSOME REPORTING REQUIREMENTS.

6. THE SUBJECT OF THE SIXTH ANALYSIS IS FUTURE METHODS OF DIRECT FEDERAL INVESTMENTS.

THE CURRENT METHODS OR MEANS OF FEDERAL FUNDING OF RESEARCH EQUIPMENT WILL BE EVALUATED. THE BENEFITS AND LIMITATIONS OF THESE METHODS AND THE PROS AND CONS OF CHANGING THEM WILL BE ASSESSED. ALTERNATIVES WILL ALSO BE EXPLORED WITH AN EYE TO MAXIMIZING THE RETURN TO THE NATION OF FUTURE INVESTMENT OF SCARCE FEDERAL RESOURCES. ONE OPTION THAT WILL BE EXPLORED IS THE FEASIBILITY OF RETURNING TO THE USE OF THE PROVEN BUT PRESENTLY UNUTILIZED MECHANISM OF GUARANTEED LOANS TO REHABILITATE UNIVERSITY RESEARCH LABORATORIES AND EQUIPMENT. AS THE COMMITTEE KNOWS, IN 1965 THE HIGHER EDUCATION ACT ESTABLISHED A GUARANTEED LOAN PROGRAM (TITLE VII-C) DESIGNED TO ASSIST WITH THE REHABILITATION OF ACADEMIC LABORATORIES, AND THAT PROGRAM PLAYED A SUBSTANTIAL LEADERSHIP ROLE IN MOBILIZING OTHER STATE, PRIVATE, AND INSTITUTIONAL FUNDS. FOR MORE THAN A DECADE, HOWEVER, THAT LOAN PROGRAM HAS NOT BEEN FUNDED. REINVESTMENT IN THE TITLE VII PROGRAM IS ONE OPTION; OTHERS WILL BE CONSIDERED.

THE PROJECT CONTRACTED WITH THE ACCOUNTING FIRM COOPERS & LYBRAND TO DO THE RESEARCH AND ANALYSIS ON SEVERAL OF THE ANALYSES: DEBT FINANCING, TAX INCENTIVES, FEDERAL AND STATE REGULATIONS, AND FUTURE METHODS OF DIRECT FEDERAL INVESTMENT. THE ANALYSIS OF OPPORTUNITIES FOR IMPROVEMENTS IN UNIVERSITY PROCUREMENT, MANAGEMENT, AND USE OF EQUIPMENT IS BEING CARRIED OUT BY A TEAM OF THREE UNIVERSITY PEOPLE: DAVID LITSTER, DIRECTOR OF MIT'S MATERIALS SCIENCE CENTER; ROBERT BOCK, DEAN OF THE GRADUATE SCHOOL AT THE UNIVERSITY OF WISCONSIN; AND JULIE NORRIS, ASSISTANT PROVOST OF THE UNIVERSITY OF HOUSTON. OVER THE NEXT FOUR MONTHS THEY WILL VISIT AND GATHER INFORMATION FROM 12 UNIVERSITIES AND 8 CORPORATE AND GOVERNMENT LABORATORIES.

PHASE II

DURING THE SECOND PHASE OF THE PROJECT, BEGINNING IN THE FALL OF 1984, THE RESULTS OF THE SIX ANALYSES WILL BE DISSEMINATED TO THE UNIVERSITY COMMUNITY. LEADING HIGHER EDUCATION ASSOCIATIONS AND SCIENCE AND ENGINEERING SOCIETIES WILL BE INVITED TO JOIN THE PROJECT AS COOPERATING ORGANIZATIONS, AND TO HOST SPECIAL SEMINARS AS PART OF THEIR REGULARLY SCHEDULED MEETINGS. REGIONAL WORKSHOPS WILL BE HELD IN SEPTEMBER AND OCTOBER 1984. THEY WILL BE DESIGNED TO PROVIDE OPPORTUNITIES FOR

TEAMS OF REPRESENTATIVES FROM UNIVERSITIES IN EACH REGION TO SHARE THEIR VARYING PERSPECTIVES ON THE EQUIPMENT PROBLEM. DURING THE WORKSHOPS EACH TEAM WILL BE INVITED TO EXPLORE THE IMPLICATIONS FOR THEIR OWN INSTITUTIONS OF ADOPTING APPROACHES IDENTIFIED BY THE PHASE I ANALYSES.

PHASE III

THE PROJECT'S FINAL PHASE WILL BE AN AGENCY BRIEFING IN WASHINGTON TO REPORT THE RESULTS OF THE PROJECT TO THE SPONSORING FEDERAL AGENCIES AND TO THE CONGRESS. A FINAL REPORT WILL BE SUBMITTED TO THE SPONSORING AGENCIES IN JANUARY 1985.

OBSOLETE FACILITIES--THE OTHER SIDE OF THE EQUIPMENT PROBLEM

ANY DISCUSSION OF THE RESEARCH INSTRUMENTATION NEEDS OF UNIVERSITIES IS INCOMPLETE IF IT DOES NOT ALSO ADDRESS THE INTERRELATED RESEARCH FACILITIES PROBLEM. MODERN RESEARCH INSTRUMENTATION INCREASINGLY REQUIRES SPECIALIZED ENVIRONMENTS, AND MANY OF OUR RESEARCH LABORATORIES ARE OBSOLETE AND INADEQUATE SETTINGS FOR MODERN SCIENCE. THEY OFTEN REQUIRE EXTENSIVE AND COSTLY MODERNIZATION OR REPLACEMENT. IT IS NOTEWORTHY THAT THE DOE HAS NOT ONLY RECOGNIZED, BUT IS ADDRESSING, THE SERIOUS PROBLEM IN ITS OWN LABORATORIES. THROUGH THE MULTIPROGRAM, GENERAL-PURPOSE FACILITIES BUDGET, THE DEPARTMENT CONTINUES TO REHABILITATE AND REPLACE OUTDATED FACILITIES AT ITS MULTIPROGRAM SITES.

THE DIMENSIONS OF THE FACILITIES PROBLEM ARE ESTIMATED TO BE CONSIDERABLE. IN 1981, THE AAU SURVEYED THE FACILITIES NEEDS OF 15 MAJOR UNIVERSITIES. IN FY 1979 THESE INSTITUTIONS ACCOUNTED FOR ABOUT 22% OF TOTAL FEDERAL OBLIGATIONS FOR UNIVERSITY-BASED RESEARCH. THE SCOPE OF THE SURVEY INCLUDED THE NEEDS OF ONLY PRESENT PROGRAMS AND FACULTY; PLANNED NEW PROGRAMS AND NEW HIRES WERE EXCLUDED. IT FOUND THESE INSTITUTIONS ABLE TO MEET ONLY ABOUT HALF OF THEIR PROJECTED NEEDS FOR REPLACEMENT CONSTRUCTION, MODERNIZATION, REPAIR AND RENOVATION, AND HIGH-COST EQUIPMENT (ITEMS CAPITALIZED AT MORE THAN $100,000). THE REPORT'S EXECUTIVE SUMMARY IS ATTACHED TO MY STATEMENT (ATTACHMENT D).

THE FACILITIES DEFICIT IS ALMOST CERTAINLY THE MOST SERIOUS LONG-RANGE PROBLEM THAT NOW CONFRONTS OUR RESEARCH UNIVERSITIES AND THE AGENCIES FOR WHICH UNIVERSITY RESEARCHERS PERFORM RESEARCH. A RECENT SURVEY BY THE UNIVERSITY OF CALIFORNIA, FOR INSTANCE, FOUND "STAGGERING" FACILITIES PROBLEMS, INCLUDING ESTIMATED NEEDS FOR CORE ACADEMIC FACILITIES ALONE TOTALING $1.6 BILLION OVER THE NEXT DECADE. TRADITIONAL FUNDING APPROACHES, THE UNIVERSITY CONCLUDED, SIMPLY WILL NOT MEET THEIR NEED FOR FACILITIES REHABILITATION AND REPLACEMENT. FAILURE TO ADDRESS THIS BACKLOG, HOWEVER, WILL CERTAINLY RESULT IN COMPROMISED INSTRUCTIONAL AND RESEARCH PROGRAMS.

WE UNDERSTAND THAT THE DEPARTMENT OF ENERGY HAS JOINED WITH THE DEPARTMENT OF DEFENSE AND WITH OTHER AGENCIES IN PLANNING A COMPREHENSIVE STUDY OF THE PROBLEM. WE ARE PLEASED INDEED THAT THE DEPARTMENT IS PARTICIPATING TO DEVELOP BOTH A BETTER UNDERSTANDING OF THE PROBLEM AND SUITABLE SOLUTIONS.

WE BELIEVE IT IS TIME FOR THE LEADING AGENCIES OF THE FEDERAL GOVERNMENT THAT FUND THE NATION'S BASIC SCIENCE PROGRAMS TO ASSIST IN THE REHABILITATION OF THOSE LABORATORIES ESSENTIAL TO EACH AGENCY'S RESEARCH MISSION AND GOALS. WE ASK THAT THE COMMITTEE CONSIDER ESTABLISHING A PROGRAM TO REHABILITATE DOE-FUNDED UNIVERSITY LABORATORIES AT A LEVEL COMPARABLE TO THE MULTIPROGRAM, GENERAL-PURPOSE FACILITIES PROGRAM--$40 MILLION.

RECENTLY THE NATIONAL COMMISSION ON STUDENT FINANCIAL ASSISTANCE (A BIPARTISAN PANEL CREATED BY P.L. 96-374, THE EDUCATION AMENDMENTS OF 1980) COMPLETED ITS REPORT, "SIGNS OF TROUBLE AND EROSION: A REPORT ON GRADUATE EDUCATION IN AMERICA." THE COMMISSION AFFIRMS THE SERIOUSNESS OF THE INSTRUMENTATION AND FACILITIES DEFICITS AND IT CALLS FOR JUST SUCH AN INVESTMENT STRATEGY FOR RESEARCH INSTRUMENTATION AND FACILITIES REHABILITATION AS THAT PROPOSED BY S.1537 DISCUSSED EARLIER IN THIS TESTIMONY. WE COMMEND THAT REPORT TO THE COMMITTEE'S ATTENTION.

A SERIOUS DEBATE LEADING TO CONCRETE PROPOSALS FOR A FACILITIES REINVESTMENT STRATEGY IS NEEDED. WE HOPE THAT THIS COMMITTEE WILL CONSIDER THE FACILITIES PROBLEM AS PART OF ITS CONTINUING DELIBERATIONS ON THE RESEARCH EQUIPMENT PROBLEM AND THE FY 1985 DEPARTMENT OF ENERGY BUDGET REQUEST.

PEER REVIEW

THE FUTURE RETURN ON ALL OF THESE ESSENTIAL INVESTMENTS, OF COURSE, WILL BE DETERMINED IN LARGE PART BY THE SOUNDNESS OF THE DECISIONS THAT THE CONGRESS AND THE DEPARTMENT OF ENERGY MAKE IN THE AWARD OF THE FUNDS. THE FUNDS OUGHT TO BE AWARDED ON THE BASIS OF SCIENTIFIC MERIT IN OPEN COMPETITION AMONG ALL INTERESTED AND QUALIFIED PARTIES. FINAL JUDGMENTS OUGHT TO BE FORMED IN AN OBJECTIVE AND INFORMED MANNER, FREE FROM ANY ACTIONS BY PARTICULAR INDIVIDUALS OR INSTITUTIONS THAT COULD SERVE TO MAKE THE AWARD OF SUCH FUNDS A MATTER OF POLITICAL INFLUENCE RATHER THAN THE QUALITY OF THE WORK TO BE DONE AND THE CAPACITY OF COMPETING APPLICANTS TO CARRY OUT THE WORK AT THE HIGHEST LEVEL.

RECENTLY THE ASSOCIATION OF AMERICAN UNIVERSITIES, THE AMERICAN COUNCIL ON EDUCATION, THE NATIONAL ASSOCIATION OF STATE UNIVERSITIES AND LAND-GRANT COLLEGES, AND THE COUNCIL OF GRADUATE SCHOOLS JOINED OTHERS IN ADDRESSING THE IMPORTANCE OF PROTECTING AND RELYING UPON THE ESTABLISHED PROCESSES OF INFORMED PEER REVIEW IN THE STATEMENTS RECENTLY ADOPTED BY THESE ASSOCIATIONS ARE ATTACHED TO MY STATEMENT (ATTACHMENT B).

DOE-UNIVERSITY FORUM

FINALLY, MR. CHAIRMAN, WE ARE PLEASED TO HEAR THAT IN THE NEXT FEW MONTHS, THE DEPARTMENT OF ENERGY WILL ESTABLISH A DOE-UNIVERSITY FORUM DESIGNED TO FOSTER A SUSTAINED DIALOGUE ON TOPICS OF MUTUAL CONCERN BETWEEN THE DEPARTMENT AND OUR RESEARCH UNIVERSITIES. THE EFFECTIVENESS OF THE DOD-UNIVERSITY FORUM GIVES US HOPE THAT THE DOE ACTIVITY WILL BE SIMILARLY USEFUL.

WE COMMEND THE DEPARTMENT FOR ESTABLISHING THE FORUM, AND WE HOPE THAT THE COMMITTEE WILL FOLLOW ITS ACTIVITIES WITH INTEREST.

THANK YOU MR. CHAIRMAN FOR THE OPPORTUNITY TO PRESENT OUR VIEWS TO THE COMMITTEE.

ATTACHMENT A

PROJECT TO ASSESS & DISSEMINATE ALTERNATIVE APPROACHES TO MEETING UNIVERSITY RESEARCH EQUIPMENT NEEDS

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ATTACHMENT B

AAU

Association of American Universities

AAU STATEMENT ON DECISION MAKING IN FEDERAL FUNDING FOR RESEARCH FACILITIES

The Association of American Universities represents institutions whose faculties are deeply engaged in research. We share with many other institutions and individuals a commitment to advancing the quality of the nation's research effort. Since the vitality of this effort is closely linked to the soundness of decisions made about science by public bodies, it is both appropriate and important for the AAU to state its collective views about the ways in which those decisions are best made.

The United States has evolved an admirable but fragile system of awarding federal funds for research. In general, Congress appropriates funds for the support of broad categories of research. Subsequently, the administering federal agency issues guidelines for making applications in a manner that assures fair and open competition. Researchers then submit detailed proposals that are judged by experts, scientists chosen for their ability to make sound and careful judgments in the scientific area involved. This method maximizes the scientific return on the federal investment by assuring that awards are made on the scientific merit of the proposal and the professional merit of the proposer.

The same method governed most federal programs in support of scientific facilities when such programs existed. However, in the early 1970s, most federal government programs in support of the construction and renovation of research facilities ended. The subsequent decade-long failure to attend to the capital base of university science has led to a backlog of need that has hampered American science and placed great stress on the processes by which the government allocates scientific resources.

We believe that processes based on the informed peer judgments of other scientists need to be preserved and strengthened. We therefore urge scientists, leaders of America's universities, and Members of Congress to support the practice of awarding funds for the support of science on the basis of scientific merit, judged in an objective and informed manner. Further, we urge them to refrain from actions that would make scientific decisions a test of political influence rather than a judgment on the quality of the work to be done. These principles should apply in making decisions about scientific facilities as well as in awarding funds for research projects.

Finally, we urge officials of the national Administration and Members of Congress to deal promptly with the decay of the physical plant that houses much of the nation's basic research. S.1537, introduced by Senators Danforth and Eagleton, is a bipartisan effort to deal with this national priority and deserves strong and prompt support.

October 25, 1983

National Association
of State Universities
and Land-Grant Colleges

Robert L. Clodius, President

STATEMENT ON FEDERAL FUNDING OF ACADEMIC FACILITIES

In recent years, federal funding of various higher education programs had decreased markedly. In particular, wholly inadequate resources for facilities has led some institutions to seek direct assistance from Congress. The outcome of such a process could be an irrational system of distribution based solely on political influence. In that regard, the National Association of State Universities and Land-Grant Colleges shares the concerns of the Association of American Universities, the National Academy of Sciences, and others, that this approach is unacceptable, in that it could diminish the capability of higher education to carry out its mission in education and research, and we urge Members of Congress and leaders of colleges and universities to refrain from this practice.

We further urge the Congress to fund Title VII of the Higher Education Act and similar programs in other agencies at reasonable levels, and to insure the systematic allocation of resources to satisfy pressing national concerns.

November 13, 1983

CGS The Council of Graduate Schools in the United States
One Dupont Circle, N.W. Suite 430 Washington, D.C. 20036-1173 Phone: 202/223-3791

RESOLUTION NO. 1

RESOLUTION IN DECISION MAKING IN THE FEDERAL FUNDING FOR RESEARCH FACILITIES

WHEREAS the United States has evolved an admirable but fragile system of awarding federal funds for research, and,

WHEREAS this system is dependent upon fair and open competition responding to federal agency guidelines, and peer review judgment by experts in the scientific area to be studied, and,

WHEREAS this method of peer review has governed most federal programs in support of scientific facilities when and where such program exist, and,

WHEREAS most federal programs to support construction and renovation of research facilities have been ended through a shifting of federal priorities, and,

WHEREAS in the absence of such programs colleges and universities are suffering a gradual increasing erosion in their ability to support state-of-the-art research in all scientific fields, and,

WHEREAS CGS member institutions share with many other institutions and individuals a commitment to advancing the quality of the nation's research effort. The vitality of this effort is closely linked to the soundness of decisions made about scientific research by public bodies.

NOW THEREFORE BE IT RESOLVED that the Council of Graduate Schools supports the recently adopted AAU Statement on Decision Making in federal funding for research facilities. CGS urges the national Administration and members of Congress to support the practice of awarding funds for research or facilities on the basis of scientific merit judged in an objective manner. CGS would further urge support for new spending authorities to support research facilities to keep our nation's investment in academic research facilities from becoming out of date.

Passed at the CGS 23rd Annual Meeting 12/83

Affiliates:
Conference of Southern Graduate Schools
Midwestern Association of Graduate Schools
Northeastern Association of Graduate Schools
Western Association of Graduate Schools

Adopted at the Board of
Directors meeting of
2/23/84

Ruth A. Abdouch
Executive Secretary
Board of Directors

AMERICAN
COUNCIL ON
EDUCATION

5. Federal Relations Report
   B. Proposed Statement on Federal Funding of Research and Instructional Facilities

For Board Approval

BOARD OF DIRECTORS
Meeting of February 23, 1984
10:00 a.m.-3:00 p.m.
Kellogg Room
One Dupont Circle
Washington, DC

AMERICAN COUNCIL ON EDUCATION
Office of the President

MEMORANDUM

TO: ACE Board of Directors

FROM: J. W. Peltason

SUBJECT: Proposed Statement on Federal Funding of Research and Instructional Facilities

DATE: January 9, 1984

Community concern has been generated by the recent attempts of several institutions to bypass the customary review process to obtain federal funding for research facilities. The Association of American Universities last fall issued a statement urging scientists, leaders of America's universities, and members of Congress "to support the practice of awarding funds...on the basis of scientific merit...(and) to refrain from actions that would make scientific decisions a test of political influence rather than a judgment on the quality of the work to be done."

Similar statements have been issued subsequently by the National Academy of Sciences, the National Association of State Universities and Land-Grant Colleges, and the American Association of State Colleges and Universities. The ACE Commission on Governmental Relations discussed this matter at its fall meeting, and recommended that the Board adopt the following statement:

"There is a pressing need for increased federal support for the rehabilitation of research and institutional facilities. Established procedures for these support programs involve a system of review to assure equitable consideration and the awarding of funds on the basis of merit.

"At a time when fiscal constraints have severely restricted many federal programs, it is especially important to sustain the process which assures systematic allocation of scarce resources. Therefore we call upon leaders of the academic community and members of Congress to reaffirm the principle of broadly representative review of project proposals in fair and open competition, so that funding decisions continue to represent the best interests of both higher education and the national welfare."

One Dupont Circle, Washington, D.C. 20036-1193
President (202) 833-4710 Vice President (202) 833-4712

ATTACHMENT C

THE SCIENTIFIC INSTRUMENTATION NEEDS OF RESEARCH UNIVERSITIES

A Report to the National Science Foundation
by the
Association of American Universities

June 1980

The Scientific Instrumentation Needs of Research Universities

EXECUTIVE SUMMARY

OBJECTIVES OF THE STUDY

- assess the current status of scientific instrumentation in major research universities
- identify factors which facilitate or impede its development, acquisition, use, and maintenance
- estimate the future consequences of present funding policies
- recommend appropriate policy changes

METHODOLOGY

- sixteen universities, six national and government laboratories, and nine commercial laboratories were visited; about 80 department heads and over 250 researchers and research administrators were interviewed in the universities; in addition, the views of approximately 60 researchers and research managers were gathered in visits to national, government, and commercial laboratories
- five fields of science and engineering were studied: physics, chemistry, biological sciences, earth sciences, and electrical engineering
- numerical data on instrumentation acquisition, age, and replacement were gathered from 14 universities and four commercial laboratories

THE PROBLEM

Instrumentation is essential for progress in experimental research. Scientific knowledge has advanced rapidly; new instruments, more costly but qualitatively superior to earlier ones, have allowed measurements previously impossible. The rate of change has been great, competition among researchers intense. The capacity of university researchers to work at the frontiers of knowledge has important consequences for the nation's future research productivity and for the training of future generations of scientists and engineers.

The federal government has adopted a variety of funding policies for the support of research instrumentation: the competitive project system, special instrumentation programs, formula grant programs, block-funded centers, federally sponsored research centers, and regional instrumentation centers chief among them. For about 15 years, federal support for basic research has gradually declined; now support levels are further strained by rapid inflation. But inflationary price increases are simply the rising baseline upon which are superimposed the frequently much larger increases resulting from instrumentation advances.

ASSESSMENT

The great diversity of instrumentation needs found among institutions visited precludes simple generalizations. However, problems in the acquisition, use, and maintenance of research instrumentation were found in all of the leading universities visited. The precise configuration of these needs and problems varies widely. The capabilities of institutions and departments to meet them do also.

University researchers face great difficulty in replacing worn-out or obsolete instrumentation and in acquiring new instruments needed for frontier research. A comparison of university instrumentation inventories with those of two leading commercial laboratories reveals that the median age of university equipment is *twice* that of the commercial laboratories' instrumentation. Even the nation's major research universities have not kept pace in meeting instrumentation needs. Researchers heavily dependent upon federal funds have witnessed grant size fall behind escalating research requirements. As a result, many work with inadequate tools that impair the pace of research, force closure of lines of inquiry, strain operations and maintenance budgets, and compromise the advanced education of graduate students.

Start-up funds for new faculty often are shrinking as costs rise. Support equipment is needed to test, calibrate, and augment primary instruments. Often it is especially difficult to fund. Funding for operation and maintenance costs is increasingly difficult to obtain. As a result, faculty and students sacrifice research time to these routine tasks.

Many research facilities are in need of renovation or replacement; federal funding for these purposes has decreased, however, and universities lack the funds to respond. Signs that aging facilities now impede research were found in many laboratories and support facilities.

Local university needs vary widely, reflecting the unique circumstances under which each institution operates and the great diversity between and even within the five fields studied. Present funding policies do not provide sufficient flexibility to deal with such local circumstances.

When compared with government and commercial laboratories visited, most university laboratories fare poorly. The best-equipped industrial laboratories surpass almost all university laboratories visited. One university researcher captured the sense of disparity and observed, "the ivory towers are now in industry." The director of one leading industrial research laboratory described the struggle of university researchers as he has observed them as "pathetic." When asked to contrast their laboratories with foreign laboratories, a number of university researchers stated that many, most notably those in Japan and West Germany, are now superior.

CONCLUSION

The quality of research instrumentation in major university laboratories has seriously eroded. Not all, but many researchers in the nation's best-funded universities are struggling to work effectively with obsolete tools. The equipment being used in the top-ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories.

Three *causes* are identified:

- a relative decrease in instrumentation support
- inflexibility within the project system
- insufficient support for maintenance

Three major *consequences* are:

- diminished research productivity
- reduced training capacity
- decline in international competitive status

RECOMMENDATIONS

Federal policy for the support of research instrumentation should provide for a basic three-part funding strategy:

- strengthen instrumentation funding in the project system
- expand special instrumentation programs
- create in the National Science Foundation a new, supplemental formula grant program to provide needed flexibility to meet diverse institutional needs

FUTURE STUDIES

Five studies are recommended: 1) a thorough analysis of foreign research funding policies and programs and their implications for the competitive stature of American science should be undertaken; 2) a study of cooperative research arrangements between industries and universities and the factors—including federal policies—that encourage and discourage them is needed; 3) the planned assessment of regional instrumentation centers should include consideration of the concerns documented in this report; 4) universities should assess current instrumentation policies and develop mechanisms and incentives designed to promote effective sharing of instrumentation; 5) an assessment of the costs and benefits of federally-mandated equipment inventory and reporting systems should be undertaken.

ATTACHMENT D

THE NATION'S DETERIORATING UNIVERSITY RESEARCH FACILITIES

A Survey of Recent Expenditures and Projected Needs in Fifteen Universities

July 1981

Association of American Universities
One Dupont Circle, N.W.
Washington, D.C. 20036

EXECUTIVE SUMMARY

OBJECTIVES OF THE SURVEY

This survey of 15 leading universities had three objectives:

-- In the institutions surveyed, document expenditures for research facilities and major ($100,000 or more) equipment, without regard to source of funds, over the last four years in the following six fields:

- Biological Sciences
- Chemical Sciences
- Earth Sciences
- Engineering
- Physics
- Medical Schools (10)

-- Provide responsible estimates, prepared by those universities, of expenditures for research facilities and major equipment that would be required over the next 3 years to meet the research and training needs of only current faculty.

-- From researchers and department heads, acquire assessments of the major consequences for science, industry, and government if the accumulating facilities needs of their institutions are not addressed.

FINDINGS

In many of the science and engineering departments surveyed, a substantial backlog of research facilities and equipment needs is accumulating. Projected funding needs over the next three years equal almost twice the level of expenditures by universities for their research laboratories and equipment over the past four years. Already, institutions often are unable to provide their basic science and engineering researchers and students with either the modern laboratories or equipment needed to conduct state-of-the-art research and education programs.

The loss of federal contributions to the support of research facilities and the absence of compensatory sources of support has forced many institutions to renovate and repair only those facilities in greatest need. Even this work often is carried out in a necessarily piecemeal fashion which is uneconomical over the long term. Working under such conditions, researchers unavoidably compromise their productivity and future competitiveness.

Relatively few construction projects have been completed in recent years in a majority of the physical sciences and engineering departments surveyed. Many institutions estimate substantial needs for new laboratories, for the expanded modernization and repair of old laboratories and for modern research equipment. Details are provided in the following report and the appendicies. The survey's principal findings are the following:

- In the last four years, for the six fields surveyed, fifteen leading universities together spent $400 million from all sources for facilities and major equipment. Half of those expenditures was for a relatively small number of new construction projects; the remaining half, spread over a larger number of generally less costly funding projects, was for facility modernization, major repair and renovation, and special purpose research equipment.

- In the next three years, the 15 universities estimate they should spend almost twice as much ($765 million) just to provide the necessary research facilities and special research equipment for current faculty only. These estimates are in current dollars and, therefore, do not include the added effects of inflation.

- New construction to replace outmoded facilities accounts for almost 60% of total projected funding requirements across all fields.

- In addition, substantial needs for major research equipment were identified in all six fields. These equipment estimates include only major items costing at least $100,000. As the 1980 AAU report to the National Science Foundation found, most departments also have serious deficiencies of less costly analytical instrumentation and support equipment.

RECOMMENDATIONS

The problems of obsolescence in the nation's university research facilities have been growing for more than a decade. To solve them, a new national investment strategy is needed. That strategy should provide direct, balanced support for university facilities from federal agencies and provide investment incentives designed to involve industry, the states, and the universities in a coordinated effort. The following steps are suggested as starting points:

1. Key Executive agencies should develop a mechanism to periodically assess the condition of university research laboratories and the consequences for the nation of that condition. Such assessments should involve the Office of

Science and Technology Policy, the National Science Foundation, the Department of Defense, the Department of Energy, the Department of Health and Human Services, the Department of Agriculture and the National Aeronautics and Space Administration. The views of industry and the universities also should be solicited.

If the initial review corroborates the assessment of this suvey the following recommendations should be considered:

2. The facilities and equipment program earlier proposed to be undertaken by the National Science Foundation but deferred should be restored as a priority initiative in FY 1983.

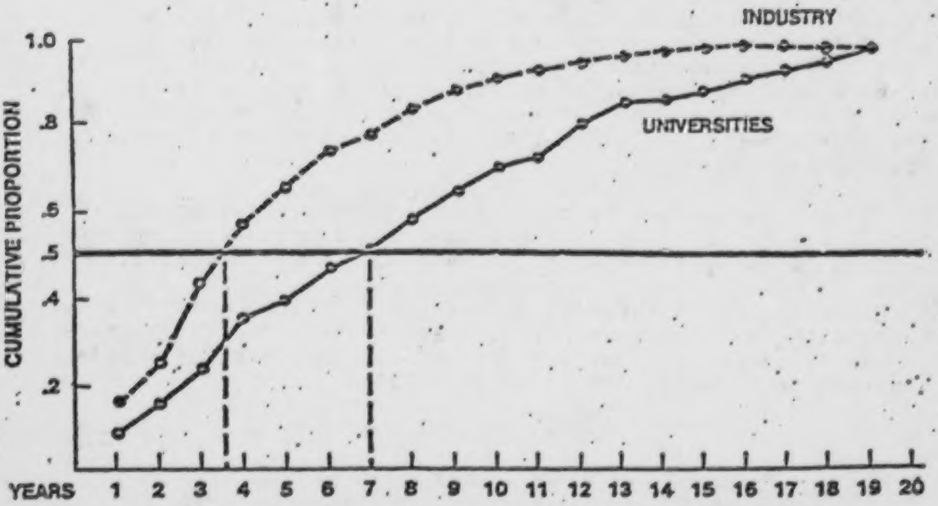
3. The Department of Defense, Department of Energy, the National Aeronautics and Space Administration, the Department of Health and Human Services, and the Department of Agriculture should establish research instrumentation and facilities rehabilitation programs targeted on the fields of science and engineering of primary significance to their missions. The National Science Foundation should assist in the development, implementation, and coordination of those activities.

4. Incentives should be provided to encourage industries and the states to join with universities and the federal government in renewing the nation's university research laboratories.

5. Interest costs incurred in the construction, modernization, renovation, and repair of facilities in which federally supported research programs are carried out should be allowable indirect costs under OMB Circular A-21.

ATTACHMENT E

Age of Instrumentation in Universities Twice That in Industry



Senator **Domenici**. Thank you very much. Doctor, let me ask with reference to the NSF and the Office of Naval Research and their fellowship program for Ph.D.'s, NSF has a significant post doctoral program, I understand.

Mr. **Rosenzweig**. That is correct.

Senator **Domenici**. That is 5 years in duration. Is that matched with private resources?

Mr. **Rosenzweig**. No, I do not believe so.

Senator **Domenici**. My staff indicated to me that was a matched program with private resources coming in with equal shares.

Mr. **Rosenzweig**. That NSF program? They may well be right. I will have to look into that; I was not aware of that.

Senator **Domenici**. The reason I was asking if it is, the National Science Foundation instituted a new progrm to provide recent Ph.D.'s with a 5-year award with $30,000 to be matching.

Mr. **Rosenzweig** These are the young investigators awards, the program for which the first class has just been announced, I believe. Yes, that is correct.

Senator DOMENICI. Do you know whether private industry is forth coming?

Mr. ROSENZWEIG. No, I do not know.

Senator DOMENICI. Is it too early?

Mr. ROSENZWEIG. I can find out.

Senator DOMENICI. Will you try to find out?

Mr. ROSENZWEIG. Yes, I certainly will.

Senator DOMENICI. I think it is interesting to get something on the record, because we do not do that in the DOE programs at all. I think maybe we could get more money and more new adjunct if we could suggest a match.

Mr. ROSENZWEIG. I think especially in the facilities area, matching funds have been the traditional way for the Government to provide money for scientific facilities and are certainly the way that we would look to in the future as new facility funds are made available.

[The information follows:]

Association of American Universities

President

April 4, 1984

The Honorable Pete V. Domenici
Chairman
Subcommittee on Energy,
  Research and Development
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

I want to thank you again for the opportunity to testify during the March 20th subcommittee hearing on the FY 1985 DOE Authorization. I would like to respond to your question regarding the role of the private sector in NSF's Presidential Young Investigator Awards program.

As you indicated in your question to me, there is a provision in the program which allows for contributions from industry to be matched by funds of the NSF. In addition to the basic award of $25,000 per year for 5 years, the Foundation will provide up to $37,500 on a dollar-for-dollar matching basis to contributions from industrial sources, resulting in potential annual support of $100,000 to an awardee.

The awardee's sponsoring institution is responsible for securing the private sector contributions. As NSF only recently announced the first awards recipients and has not yet received all of the sponsoring institutions' budgets, it is too early to evaluate the success of the matching funds option. Since this option is aimed at developing improved links between the academic and industrial sectors, we would expect that participating institutions will make every effort to increase support for their young faculty. We will be following the progress of the program with great interest.

We support the goals of this important program to provide the necessary support to promising young faculty committed to academic research careers. As stated in my testimony, a similar program in the Department of Energy to support young academics pursuing research careers in energy-related fields would enhance the human resource pool in those areas.

Please contact me if we can be of any further assistance.

Sincerely,

Robert M. Rosenzweig

Senator DOMENICI. Dr. Dean, we are going to make your statement a part of the record and you may proceed.

STATEMENT OF DR. STEPHEN O. DEAN, PRESIDENT, FUSION POWER ASSOCIATES

Dr. DEAN. Thank you, Senator. It is a pleasure to be here again. Our Fusion Power Associates, as you know, is a nonprofit corporation established in 1979 to assist in the development of fusion. We have 46 industries, utilities, and universities as members and over 400 individuals.

I would like also to make a part of the record a policy statement by our board of directors that also contains a list of our members.

I would just like to make one additional point. It was in fiscal year 1976, about 9 fiscal years ago that the Congress approved the tokamak fusion reactor at Princeton University to demonstrate fusion break-even. That machine is now finished and in operation and no additional facilities have been authorized since that time. That is 9 years.

In that time the Europeans and the Japanese have undertaken devices which are more ambitious and larger than the best device that we have. In 1980, the Congress passed a law saying that we should go on with the next facility and have it operational by 1990. As you know, since that time, 4 years ago, nothing has happened to initiate any new facility in the fusion program.

The U.S. Fusion program is losing momentum. It is losing leadership and unless we embark on a next generation facility very quickly, I think the United States is going to very quickly become second best in the international race to harness fusion energy.

Already the fact that we are not building any new facilities means that the Japanese industry is gaining much more experience than our industry in this important new technology area. We have a proposal that has been under development now for several years in various forms and it is still a proposal. It is to build a facility which at the moment carries the name tokamak fusion core experiment, which would generate 300 megawatts of fusion power for 5 minutes. This is a considerable advance over anything that would be available in the world today and I urge the Congress to urge the department to get that project underway as rapidly as possible.

This does not mean that this concept will ultimately be the best commercial product. We need to maintain our ultimate concepts. We need to continue to look at our reactor designs so that in the end we build a fusion power reactor that the utilities would want. I think the department attempts to manage a good well-rounded broad program, but in the present financial climate, especially with the attitudes of not committing to make a new facility it is almost impossible for this program to do anything but slowly deteroriate.

I am very concerned about this and I urge the Congress to do everything it can to urge the department and the executive to get on with the building of the next generation of fusion facilities.

Thank you.

[The prepared statement of Dr. Dean follows:]

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STEPHEN O. DEAN
PRESIDENT

STATEMENT OF
DR. STEPHEN O. DEAN
PRESIDENT
FUSION POWER ASSOCIATES
TO THE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
OF THE
SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES
MARCH 20, 1984

It is a pleasure to have the opportunity to address your subcommittee as you consider the Department of Energy's FY 1985 funding request for fusion energy research.

Fusion Power Associates is a non-profit corporation established in 1979 "to ensure the timely development and acceptance of fusion as a socially, environmentally and economically attractive source of energy." Forty-six industries, utilities, and universities and over 400 individuals are currently members or affiliates of Fusion Power Associates.

The Department of Energy request for magnetic fusion energy is primarily for continuations of existing strong efforts in tokamak and magnetic mirror confinement activities, combined with efforts in supporting research, technology and alternate concept development. The department's budget represents a reasonably balanced effort among the various disciplines and concepts required for fusion development.

We meet today at a time when the Alcator C device at MIT has recently achieved, for the first time in history, the quality of confinement required for net fusion energy release. This degree of plasma confinement, referred to as the Lawson Product, and expressed as the product of the plasma density and its energy confinement time, has been a major milestone goal of the fusion program for over 25 years. The achievement of this goal in late 1983 was an historic event.

Even as this event was occurring, however, early results from the next generation of fusion devices, TFTR in the U.S. and JET in Europe, were coming in. The energy confinement times already achieved in those devices, about three-tenths of a second, are about 10 times longer than in Alcator C, exceed our original expectations for those devices and give us further confidence that we are in position to proceed with the initiation of the next generation of device--to achieve ignition and the sustained release of fusion power. Such a device, if authorized now, could be operational in the early 1990's. Recently the DOE's Energy Research Advisory Board (ERAB) called the initiation of such a device (which they call BCX for Burning Core Experiment) "essential to sustain momentum and focus of the program." I support their recommendation.

"TO TAKE FROM THE SEA
AND TO IMITATE THE SUN"

The Board of Directors of Fusion Power Associates has recently reviewed the present status of fusion development and urges that fusion energy development be based upon the following recommended policies:

- The expeditious development of practical fusion power should receive high national and international priority.
- The engineering aspects of fusion development require substantial additional effort now.
- Commitments to new and improved experimental facilities are urgently needed to insure continued program momentum and progress into the 1990's.

Progress in fusion energy development requires the periodic initiation of facilities which incorporate and take advantage of advancing state-of-the-art knowledge. Such facilities are characterized by improved values of performance parameters such as total fusion energy released and power density. It should be an objective of the fusion program to initiate commitments to such facilities on a timely basis and to manage research and development activities to assure their success.

The near-term objectives of the fusion program are to carry out integrated scientific and engineering activities to provide the basis for identifying and evaluating the most promising concepts for commercial application. There should be a heavy reliance on conceptual reactor design studies to guide the R&D program, which should be based upon clear program and project objectives, plans and milestones.

Although the requirements for commercially attractive fusion systems cannot be specified precisely at this early date, the need for improvements in present concepts is evident. Reactor embodiments of fusion concepts based on present science and technology would not be commercially competitive today. This situation is not at all surprising in light of the fact that fusion energy is still in a comparatively early stage of development. However, it does require continued attention to the search for more cost-effective fusion concept embodiments. Fusion program managers should give this search high priority and high visibility in program descriptions and in their decision-making activities.

Although physics programs require the bulk of fusion program funding at this time, a clearly-established and well-maintained reactor engineering program is equally essential. It should be an objective of the fusion program to ensure balanced effort and good coordination among the various essential elements of the program, e.g., physics innovation, parameter demonstrations, technology development, systems analysis and reactor conceptual design, and to stimulate the development of fusion capability in U.S. industry.

Finally, it should be a program objective to continuously improve and implement a coordinated management system. A strong and effective management system can accelerate pace by focusing efforts and reallocating resources.

Senator DOMENICI. I thank you very much, Dr. Dean. In your statement you stated that there should be a heavy reliance on conceptual reactor design studies to guide the R&D program. Do you believe that we are doing enough in the department in that way?

Dr. DEAN. Aboslutely not. The last tokamak fusion reactor, commercial reactor design, the Starfire, was completed in 1980. That is 4 years ago and we have not updated that study since. We just finished a mirror reactor study last year and there is no intent to follow up on that now to really take advantage of all of the things we learned in that study.

I think reactor designs need to be continuously done, ongoing, always identifying problems, always proposing new solutions and they ought to be always up to date. It is this kind of problem that these things are not up to date that resulted in the recent flurry of activity from an article at MIT, saying that fusion reactors were not attractive to the utilities. We have got to come up with reactor designs that are attractive to the utilities and the only way to do that is having continuous ongoing groups studying those problems.

Senator DOMENICI. I wanted to ask you one additional question. I did not get a chance to review your statement, your indepth statement, but I noticed one of the things you were addressing was the impact of the 1981 tax law, which purportedly created some additional incentive for giving in the area of university research capability by way of changing the law and how it could be done by both business and individuals. Have we had enough experience for you to just quickly tell us if it is working?

Mr. ROSENZWEIG. I think it has been moderately successful. It has not achieved everything that was hoped for it, but the situation is better than it would have been had the law not been changed. I guess yesterday's action by the finance committee in which it extended that provision and changed it in some technical respects ought to improve the situation still further and make it more attractive for industry to support research in universities as opposed to supporting, putting additional funds in their own in-house research.

Senator DOMENICI. I think we ought to, as institutions and associations, you ought to monitor that closely and keep us posted.

Mr. ROSENZWEIG. Indeed.

Senator DOMENICI. Because if you look out there in the marketplace every time we succeed in finding a way so that we have got the sensitivity of the taxpayer in terms of tax benefits, marvelous things happen. I do not know if you are familiar with the old buildings that we used to try and renew under urban renewal and the like 5 or 6 years ago. We changed the Tax Code in the remodeling of these old buildings and I think there was more improvement that occurred in delapidated, downward trending central business districts from that than all of the urban renewal. I am not sure about that, but I think so.

Mr. ROSENZWEIG. I am a great believer, Senator, in using the Tax Code to unlash private energies for public purposes. That is sort of a countercyclical view these days. All of the political attention seems to be directed toward closing tax loopholes and I am in favor of closing tax loopholes also, but not those particular ones.

Senator **Domenici**. That is our dilemma. With that, we will be in recess. Thank you very much.

[Whereupon, at 3:15 p.m. the hearing was adjourned, subject to the call of the Chair.]

APPENDIX III

RESPONSES TO ADDITIONAL QUESTIONS

Department of Energy
Washington, D.C. 20585

May 4, 1984

Honorable J. Bennett Johnston
United States Senate
Washington, D.C. 20510

Dear Senator Johnston:

With your April 23 letter we received five sets of questions for our response to be included in the printed record. One set of questions related to the March 20 hearing when the Director of Energy Research, Alvin W. Trivelpiece, testified on the authorization for energy research.

Enclosed are answers to the questions on energy research.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H. Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Al Astrin

Questions for Dr. Alvin Trivelpiece

New Facilities

Question: Your statement describes several planned "next generation" facilities for high energy physics, nuclear physics, fusion research, and materials research. Among these are:

- the Superconducting Super Collider, a high-energy physics facility for which R&D and design work is proposed in the FY 1985;
- the continuous electron beam facility proposed by the Southeastern Universities Research Association for construction at Newport News, Virginia, for which construction will be initiated in FY 1985;
- the Center for Advanced Materials at Lawrence Berkeley Laboratory; and
- the Tokamak Fusion Core Experiment, currently under design.

Before we become too committed to these facilities, there ought to be some indication of what their total cost is going to be. For each facility, please provide the following information.

(a) total estimated cost and the uncertainty in this cost;

Answer:

SUPERCONDUCTING SUPER COLLIDER

We are in the very preliminary conceptual phase of the Superconducting Super Collider; the Department has not committed to recommending its construction. It is therefore impossible to discuss specific construction costs and schedules. We have underway a Reference Designs Study whose purpose is to define the scope of the SSC more clearly and to provide a meaningful cost estimate. The Reference Designs Study is expected to be completed by June, 1984. It will then be reviewed, and a preliminary cost estimate established in August, 1984. Until this study is complete, the project cost is speculative. We will let you know the projected project cost, when that number is available.

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY

Exact construction costs and the project schedule for the Continuous Electron Beam Accelerator Facility (CEBAF) are presently under review. At this time, we estimate that CEBAF construction costs will not exceed $225 million. This estimate is based upon our review of a draft Conceptual Design Report submitted to us by the Southeastern Universities Research Association (SURA) and a formal review of the CEBAF construction project. This review was conducted on February 27 and 28, 1984, by Department of Energy Headquarters and Oak Ridge Operations Office staff.

CENTER FOR ADVANCED MATERIALS

The Center for Advanced Materials (CAM) consists of a new research program or concept which will involve focused materials research with substantial participation by United States industry. To undertake this research, two new buildings are proposed which together will house the CAM activities. One facility, the Surface Science and Catalysis Laboratory (SSCL) was initiated in FY 1984, and is an addition to an existing building at Lawrence Berkeley Laboratory (LBL). This laboratory will house the research areas related to catalysis and surfaces. A second building, the Advanced Materials Laboratory (AML), will house the remaining research areas such as ceramics, polymers, electronic materials and others.

The total estimated cost for the entire CAM construction project is $40.250 million. Included in the total cost is a contingency of $6.040 million which should cover any uncertainty in this estimate.

TOKAMAK FUSION CORE EXPERIMENT (TFCX)

The situation for the TFCX is similar to that of the SSC: the Department is doing preconceptual design and relevant R&D, but has not committed to recommending construction. An accurate cost estimate will be possible only after completion of a conceptual design that is to begin late in FY 1984 and be finished early in FY 1986.

In answering your questions, we will use projections based on systems studies of various previous construction projects, including the TFTR, which is similar in size, and the MFTF-B Mirror Machine, which has advanced magnet technology.

These preliminary studies suggest a range of the TEC for various machine configurations from as low as $700 million to approximately $1.3 billion. In all cases, it is assumed that the machine is located at a site where facilities exist that are required for the construction and operation of the machine.

The range of total cost does not indicate an uncertainty in cost of the machine. Rather, the uncertainty is the range of costs of different machine configurations, each of which meets the basic objectives of a TFCX project. These configurations differ in their capability to be upgraded to higher levels of performance or in their use of technology that is relevant to a future engineering reactor. When the machine configuration is selected and a conceptual design is completed in mid FY 1986, a specific and an accurate cost estimate will be prepared. Uncertainty in the TEC at that time is expected to be less than 25%.

Question: (b) portion of the FY 1985, 1986, 1987, 1988 and 1989 budgets to be devoted to the project. Please indicate R&D, design and construction spending, and include work on each project supported by DOE from all sources; and

Answer:

SUPERCONDUCTING SUPER COLLIDER

As stated in the previous answer, there is neither a firm cost estimate nor an established construction starting date for the SSC. We therefore cannot give an itemized answer to this question. However, the FY 1985 President's budget request includes $20M for SSC R&D. We do estimate for a project of this size that an additional $150 million will be required to carry out and complete preliminary R&D efforts. Depending upon progress made during the preliminary R&D efforts, the amount of R&D may be increased or decreased.

Although some very preliminary discussions have been initiated with other countries, there are no commitments for funding from any other source at this time.

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY

Exact construction costs, funding profile, and project schedule for the Continuous Electron Beam Accelerator Facility (CEBAF) are presently under review. At this time, we estimate that CEBAF construction costs will not exceed $225 million and that construction will be completed in FY 1990. In addition to construction costs, we estimate that $25 million in R&D over the FY 1984-1989 period will be required for the CEBAF project. The FY 1985 Budget Request provides $5,000,000 in Operating Expenses for R&D in support of the CEBAF project and $2,000,000 in Construction funds for initiation of CEBAF construction.

Our present, tentative estimate of the CEBAF funding profile is:

CEBAF Project
(B/A in thousands of dollars)

	FY 1984	FY 1985	FY 1986	FY 1987	FY 1988	FY 1989	FY 1990
Construction	$ 0	$ 2,000	$40,000	$50,000	$50,000	$50,000	$33,000
R&D	2,000	5,000	6,000	6,000	4,000	2,000	0

CENTER FOR ADVANCED MATERIALS

The following resources are estimated to be required for the CAM project.

Fiscal Year	Appropriation ($ in millions)
1984	$ 1.760
1985	10.790
1986	14.440
1987	13.260

These amounts include design and construction. There is no R&D needed for the CAM construction project.

TOKAMAK FUSION CORE EXPERIMENT (TFCX)

The FY 1985 budget includes about $6.0 million for direct support of TFCX device specific design efforts. Additionally, the Fusion Engineering Design Center and other fusion laboratories are conducting ongoing studies which will now support the TFCX design. A FY 1986 funding request has not yet been established. If the Department decides to recommend construction, funds will not be requested before FY 1987, and requested funding in FY 1987, 1988, and 1989 will be based on results of the conceptual design but should not exceed 25-30% of the total program cost.

There is no other support for TFCX from other parts of DOE or other agencies of the Government. The Magnetic Fusion Energy Development and Technology subprogram will direct part of its R&D contractor work to meet near-term technology needs of TFCX. This can be done within the scope of this subprogram since the subprogram has been focused on TFCX-relevant development activities for many years.

Question: (c) total five-year costs (FY 1985 - FY 1989) in each of these categories and as a percentage of DOE funding under the relevant budget heading (High Energy Physics, Nuclear Physics, Basic Energy Sciences and Magnetic Fusion Energy).

Answer:

Since we do not know what budget packages will go forward for FY 1986 and future years, no percentage of the budget can be estimated.

SUPERCONDUCTING SUPER COLLIDER

In FY 1985, $20 million is requested for SSC R&D. The percentage of the High Energy Physics budget required for SSC R&D in FY 1985 is 4%. If and when a construction project is committed to, the amount may increase.

It is clear that a decision to construct the SSC could not be accommodated within a constant HEP budget.

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY

Exact construction costs, funding profile, and project schedule for the Continuous Electron Beam Accelerator Facility (CEBAF) are presently under review. At this time, we estimate that CEBAF construction costs will not exceed $225 million and that construction will be completed in FY 1990. In addition to construction costs, we estimate that $25 million in R&D over the FY 1984-1989 period will be required for the CEBAF project.

Upon completion, we expect CEBAF to require an annual operating budget of approximately $15 million in FY 1984 dollars for facility operations. Facility operations includes all costs of operation and maintenance of the accelerator complex, permanently installed equipment, and the physical plant--that is, all costs of delivering beam for use by research scientists. In addition, an annual budget of about $5 million will be required for research by CEBAF staff and for plant and instrumentation improvements.

For comparison, the three largest accelerator facilities in the Nuclear Physics program have FY 1984 facility operations budgets of $33.5 million for the Clinton P. Anderson Meson Physics Facility, $17.3 million for the Bevalac, and $5.4 million for the Bates Linear Accelerator Center.

CENTER FOR ADVANCED MATERIALS

Total costs for the CAM project are $40.250 million for Fiscal Year 1984 through 1988. The costs of the project designated in A above for FY 1985 - FY 1989 are $38.490 million. FY 1984 costs are $1.760 million. As a percentage of Basic Energy Sciences estimated funding for FY 1985-FY 1989, this amounts to about 1.7 percent.

TOKAMAK FUSION CORE EXPERIMENT (TFCX)

Without yearly budget estimates for the TFCX project, it is not possible to accurately specify the five year totals.

Question: (d) Please explain in each case why the commitment in resources at the level you propose is justified in view of the increasingly severe competition for Federal research funds for civilian purposes in the coming years.

Answer:

SUPERCONDUCTING SUPER COLLIDER

The Administration is committed to maintaining the excellence of U.S. science and has determined that a major step forward in capability for the high energy physics program is an important ingredient for achieving this national goal. It is recognized, of course, that large and costly research facilities such as SSC do have significant impact in the competition for research funds. For the U.S. to maintain its excellence and world standing in science, it is necessary to determine which facilities are required to keep the U.S. on the forefront of scientific exploration and then seek appropriate means to bring these facilities into reality. In proceeding with plans for major new facilities, we will take all steps possible to control the costs to the U.S. of the new facilities themselves, and to maintain control on the overall costs of the programs in which these facilities are located. In this regard, Secretary Hodel has withheld making a full commitment to the SSC until he has had a chance to evaluate a credible cost estimate to be assured that the SSC can be achieved at an affordable cost. In addition, we are exploring ways to achieve international participation and cost sharing in the SSC.

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY

The Administration gives high priority to supporting such forefront basic research activities as nuclear physics at a level which maintains their vitality and world-competitiveness. Federal support of basic nuclear research is this Nation's long term investment in its technological future with nuclear processes--trained manpower, knowledge base, and advanced instrumentation. Based upon extensive peer review, including formal examination by the DOE/NSF Nuclear Science Advisory Committee, the American research community has determined that the highest priority for new accelerator construction in the United States nuclear physics program is for an electron accelerator with the properties proposed for the Continuous Electron Beam Accelerator Facility (CEBAF).

The CEBAF's 4 GeV energy and its continuous, high intensity electron beams provide a unique opportunity to investigate the ways in which the quarks bound in neutrons and protons influence the makeup and behavior of nuclei, to determine how quarks interact while imbedded within nuclear matter, and to test quantum chromodynamics as the fundamental theory of the strong nuclear force. Experiments in which electrons knock protons, neutrons, or even excited states of protons and neutrons out of nuclei will yield information about how energy and momentum is distributed among the protons and neutrons which are bound inside nuclei. These experiments will also tell us how neutrons and protons group together inside nuclei.

CENTER FOR ADVANCED MATERIALS

The commitment to CAM is justified because the project will provide a scientific data base to support the nation's economy in the long term by making U.S. industry more competitive with that of other countries. The aim of CAM is to provide a vehicle for applying the expertise of a major national laboratory to subjects of interest to U.S. industry. Industry has responded enthusiastically by participating in the workshops organized to scope-out the research subjects to be investigated. Furthermore, the advantage of having new graduate students/new scientists trained in these areas at LBL, which is intimately involved with the University of California, provides added justification. CAM will help the civilian needs of the nation by providing a source of new talent in materials research, the backbone of most high technology commerce--the new industries of the future.

TOKAMAK FUSION CORE EXPERIMENT (TFCX)

The magnetic fusion energy research and development program is an integral part of the National Energy Policy Plan for the preparation of new energy sources for the long term future of the country. In determining the President's request for fusion, the Department has weighed the excellent progress being made, the great potential benefit of fusion, the cost of answering the necessary technical and scientific questions as well as the length of time until primary benefits can be realized. Given the severe competition for funds, a general consensus has been reached in the Administration that an approximate level of effort budget is appropriate for fusion. At this budget level, we have considered the programmatic need for effective use of past and current investments in fusion. There is a consensus that an ignition and long burn facility should be started soon to capitalize most directly on this past investment in people and facilities. The Department is now seriously considering such a commitment with a clear picture of the competition for civilian research funds. We are attempting to define a suitable facility (TFCX) to achieve this objective. At present, it appears that commitment to a TFCX could be made within an essentially constant budget during design and probably require only a modest increase during construction years. In this regard, Secretary Hodel has withheld making a full commitment to the TFCX until he has had a chance to evaluate a credible cost estimate to be assured that the TFCX can be achieved at an affordable cost. In addition, we are exploring ways to achieve international participation and cost sharing in the TFCX.

International Cooperation

Question: What is DOE's assessment of the potential for international cooperation to share the costs of large expensive facilities such as those discussed in the question above?

Answer:

SUPERCONDUCTING SUPER COLLIDER

Since the SSC is a new effort that began to receive serious consideration less than a year ago, we have only had the opportunity for very preliminary exploration of the possibilities for international participation in SSC. The possibility of participation in SSC was discussed during the March 1984 visit to Japan of a delegation which was headed by the President's Science Advisor, Dr. George Keyworth, and of which I was a member. I can report that the general reception by the Japanese was very favorable, although no specific proposals were presented or discussed. It is difficult to give any definitive assessment at this early date. However, Japanese scientists and engineers were invited to a technical review and planning meeting on the SSC this summer in the U.S. They plan to send about 10 representatives.

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY

The Continuous Electron Beam Accelerator Facility (CEBAF) is planned as a single purpose, national accelerator facility whose objective is to advance basic nuclear research in the United States. CEBAF's research capabilities will be unique in the world and will be available to all the Nation's scientists for nonproprietary work on the basis of scientific merit and technical feasibility of proposals reviewed by peer committees called program advisory committees.

We anticipate no direct foreign cost sharing to construct this facility. On the basis of reciprocity, that is, reciprocal American access to unique facilities operated by foreign countries, we expect foreign scientists to participate in the CEBAF project by collaboration in experiments and development of instrumentation. We conclude that this form of international cooperation is best for the CEBAF project.

CENTER FOR ADVANCED MATERIALS

International cooperation to share the costs of CAM does not seem appropriate. One of the main objectives of CAM is to assist U.S. industry to become more competitive. Insofar as interacting with individual scientists from other countries, this will be done on a case-by-case basis where it is advantageous to the U.S.

TOKAMAK FUSION CORE EXPERIMENT (TFCX)

The possibility of significant sharing of costs for large facilities exists. The prerequisite for achievement of such cooperation is that potential participants must need a facility with roughly similar scope, priority and, especially, timing. In the particular circumstances of the fusion program vis-a-vis TFCX, the other major programs (European Community and Japan) are just bringing into operation their current generation of large facilities (JET and JT-60). These facilities have full capabilities, which will be greater than our TFTR. However, whereas TFTR should achieve energy breakeven in 1986, the foreign machines will not be fully utilized before the end of this decade. For this reason, there is not a complete match in interests and timing between the U.S. and foreign fusion programs. Nonetheless, it is certainly possible that a significant level of interest can be developed. Any specific cost savings would depend upon the interests of all parties, the complexity of management arrangements, and other nontechnical requirements. It is, therefore, premature at this time to speculate on the magnitude of any possible cost savings to the U.S.

Question: What is DOE doing to investigate this possibility?

Answer:

SUPERCONDUCTING SUPER COLLIDER

In addition to the visit of the U.S. delegation to Japan discussed above, we plan to pursue all reasonable avenues to achieve international participation in the SSC. We already have a very good framework for international cooperation in high energy physics, which includes very substantial joint participation in the fabrication and funding of large, expensive detector facilities and joint use of each area's unique research facilities. Joint participation in the construction of a new facility would require a departure from the typical present mode of cooperation in which each country builds and operates unique facilities and other countries participate and share in the research program using the facilities. One forum for such discussions is the High Energy Physics Working Group associated with the series of meetings of the Versailles-Williamsburg-London Economic Summit. However, Western Europe already has major long-term efforts of its own under way and is not a likely candidate for substantial participation in building the SSC. On the other hand, it should be noted that the unique facilities under construction by the Europeans are expected to also be available for use of U.S. scientists by continuation of present practices, and we would expect use of the SSC by Western European scientists on a similar basis.

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY

With DOE support and encouragement, CEBAF scientists maintain close contact with accelerator technology development in Western Europe and Japan. We have used and will continue to use results of foreign research and development work and the expertise of individual foreign scientists. For the CEBAF project, we expect this mode of cooperation to be most beneficial.

CENTER FOR ADVANCED MATERIALS

As discussed above, this question is not applicable to the CAM project.

TOKAMAK FUSION CORE EXPERIMENT (TFCX)

Secretary Hodel has testified before Congress on his views that international collaboration is important in any consideration of new, large facilities. DOE is proceeding with the exploration of possible cost savings through international cooperation in many ways. At the senior policy level, the Department is representing the U.S. as co-leader in the Fusion Working Group set up following the Versailles Summit of Industrialized Nations. This Working Group is considering the broad political framework required for progress toward more effective international collaboration in fusion. In addition, the Department is currently developing technical options for proceeding with international collaboration in fusion. The Office of Fusion Energy is conducting discussions with foreign program leadership to ascertain interest and to develop bases for building closer collaboration. In support of this activity, the Office of Fusion Energy has requested the NAS/NRC to examine the entire issue of international collaboration with special attention to possible consequences of different courses of action. This group has recently visited senior policy officials and technical leaders in Japan and will similarly visit European leaders soon.

Additionally, the Department is pursuing with the other national programs the possibility of joint construction of a materials irradiation testing facility for fusion under the aegis of the IEA. This experience is providing useful experience in identifying impediments to project collaboration.

Question: In each case what sort of role is envisioned for the U.S. and what role is planned for each of the countries with whom we might cooperate?

Answer:

SUPERCONDUCTING SUPER COLLIDER

Since we are at such an early stage of the SSC program and only limited very preliminary discussions about international participation have taken place, it is difficult to indicate what the roles of foreign participants might be. The U.S. has established the basic goals and parameters of the SSC and is in the process of establishing the basic design features of the facility.

We expect that should a foreign participant contribute substantially to the cost of building the SSC, they would expect and should receive an appropriate role in decisions regarding facility design, construction, and operation.

CONTINUOUS ELECTRON BEAM ACCELERATOR FACILITY

For the Continuous Electron Beam Accelerator Facility (CEBAF) project, we plan that international cooperation be in the form of CEBAF use of results of foreign research and development and the expertise of individual foreign scientists and in the form of foreign scientists collaboration in experiments and development of instrumentation for CEBAF. The interesting physics to be done with a high energy, continuous beam electron accelerator has attracted worldwide scientific interest.

CENTER FOR ADVANCED MATERIALS

As discussed above, this question is not applicable to the CAM project.

TOKAMAK FUSION CORE EXPERIMENT (TFCX)

In the TFCX case, the Department must determine the timing of the TFCX within the DOE program at which time a firm role can be determined for international participation in the project.

Magnetic Fusion

Question: (a) When does DOE expect to achieve ignition and a more than momentary burn in the magnetic fusion program? What are the necessary steps to achieve this?

Answer: (a) DOE expects to achieve ignition and more than momentary burn in the Tokamak Fusion Core Experiment device discussed under "New Facilities." This device will be designed to achieve ignition and equilibrium burn of several hundred seconds to show that the fusion process can operate under conditions of self-heating. The necessary steps to achieve ignition and burn are to continue successful operation of the TFTR machine at PPPL through energy breakeven, obtain rf heating and current drive results from present confinement experiments, complete R&D on critical TFCX technology issues of magnet design, impurity control and high heat flux components, and design and construct TFCX. The time frame in which this can be achieved depends upon a decision to commit to this facility by the Secretary of Energy.

Question: (b) What is the chance that international collaboration will achieve ignition and burn at lower costs in the U.S.? Is cost control the main reason to be interested in such cooperation?

Answer: (b) It is inevitable that international collaboration will be more complex and more time-consuming than proceeding solely nationally. If significant delays occur as a result, no cost savings may occur. However, real technical benefits could be derived from foreign participation which could reduce the risk and perhaps the cost of the facility.

The principal motivations for such potential collaboration is the possibility for enhanced technical progress and not solely cost reduction.

Question: (c) Compare progress in fusion so far to the progress that needs to be made in order for fusion to be useful as an energy source. At what point in development would the nuclear fission program be if it had accomplished as much, and had as much to accomplish, as the fusion program?

Answer: (c) The U.S. magnetic fusion program has grown from a small research program in the 1950's to the present mission-oriented research and development program. The early program consisted mainly of small-scale experiments to study basic plasma physics. In the 1970's the program was expanded to study the plasma physics of near-reactor grade plasma conditions. As a result of the scientific and technological advances of the 1970's, the fusion program has started preparations for the energy breakeven experiment scheduled for completion on the TFTR facility in 1986. Although much scientific work remains to be done on individual physics and technological problems which are now under investigation, only the scientific issues of full ignition and long burn remain unexplored. These issues could be addressed in the TFCX facility as early as 1992. This facility will also stimulate the development of some of the required technology to the full reactor scale. Given the current progress, it is reasonable that a sufficient scientific and technological base will exist by the turn of the century to support the start of an engineering development program leading to commercial application.

Fusion is much more difficult scientifically than fission. Fusion experiments required to resolve scientific issues therefore require much more technology development than fission scientific facilities did. As a result fusion technology and science are developing more in parallel than was the case with fission development. The programs do not have an analogous development path nor can one compare timescales for development directly.

Question: (d) When will the private sector likely support a significant share of the costs of fusion power development?

Answer: (d) The private sector is involved and is presently supporting to a limited extent the science and technology necessary for the development of fusion energy. As the technical base for a useable fusion system is developed, which will allow the economics of the fusion energy source to be better defined, the private sector should support a more significant share of the costs of fusion power development. DOE expects that the earliest period for this to occur, given the present schedule, will be the early part of the next century.

Question: (e) Has DOE essentially committed itself to one or two fusion concepts, or is it likely that new concepts will appear through which fusion will become useful? What is DOE doing to develop such concepts?

Answer: (e) Although it is convenient to discuss progress in terms of fusion "concepts" there are in reality only two basic approaches to confining a fusion plasma with magnetic fields, the open and closed magnetic systems. All of the magnetic fusion "concepts" are variations within these basic approaches. With minor exceptions, these "concepts" require the same technology base and rest on much the same scientific base. We are utilizing the best performing "concept" within each basic category, the tokamak for the closed system and the tandem mirror for the open system, to extend the scientific base into the reactor plasma regime. We are supporting other "concepts" or variations within these two basic categories to broaden our scientific understanding. The purpose of all of this work is to assemble a sufficient base of scientific understanding of fusion plasmas so that a fusion reactor with optimum properties can be designed. This program is succeeding as can be seen from the increasing number of adaptations of specific discoveries in one "concept" to improve the performance of another. If current trends continue, it is quite likely that improved "concepts" will continue to emerge from the fertile scientific program. However, because of the advance in scientific understanding over the past decade, these "concepts" should be more clearly recognizable as improvements to the emerging fusion reactor concept which is the ultimate goal of the program.

The RIGGATRON

Question: Apparently a House subcommittee has suggested that DOE support the development of a fusion concept known as the RIGGATRON. Please explain how the RIGGATRON is supposed to work and how it would differ from the principal concepts now receiving DOE support.

Answer: The RIGGATRON is derivative of the high field tokamak concept developed by DOE. The last review of the RIGGATRON by DOE was in 1979. Hence we do not have an adequate data base on its present state of development to be able to draw sound technical conclusions on the difference between the concepts supported by the Office of Fusion Energy and the RIGGATRON as it is now configured.

Question: Has this concept ever been reviewed by DOE? What were the results?

Answer: The Office of Fusion Energy (OFE) reviewed the RIGGATRON concept in 1978 following the completion of the preliminary design work funded by OFE. An independent review panel assembled by OFE concluded that the RIGGATRON concept did not have sufficient promise either as a reactor concept or as a science experiment to merit further funding from OFE. The negative conclusion was based on consideration of problems associated with radiation damage, high mechanical stress, the ability of the design to produce net power and physics assumptions used by INESCO in predicting performance.

I have asked the Magnetic Fusion Advisory Committee (MFAC) to conduct a review of concepts that produce high energy density plasmas. This review could include the RIGGATRON if INESCO should so wish. This review will involve public technical review of the various high energy density plasma confinement and heating concepts.

Following the OFE panel review, a review of the RIGGATRON concept was performed for DOE by a group of ad hoc experts who independently of OFE issued a report on November 20, 1979, which for similar reasons recommended that the RIGGATRON concept was not promising enough to warrant further Federal funding. At present, DOE does not have a proposal from INESCO to be considered for support.

Question: Do you believe that the RIGGATRON can produce economical power? When?

Answer: As was indicated above, the design of the RIGGATRON has undergone developmental changes since DOE funded preliminary design. Since we do not have first-hand detailed knowledge of the present stage of RIGGATRON development we cannot comment on whether or when the device can produce power.

Department of Energy
Washington, D.C. 20585

March 22, 1984

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
Research and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On March 20, 1984, Dr. Alvin Trivelpiece, Director of the Office of Energy Research, appeared before your Subcommittee to discuss the authorization for energy research.

Following that hearing, written questions were submitted for our response. Enclosed are the answers to those questions.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H Pretorius

for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Al Astrin

QUESTIONS SUBMITTED BY SENATOR JOHN W. WARNER

Nuclear Physics

(1) Question: Can you describe to the committee in layman's terms the purpose of the Continuous Beam Electron Accelerator Facility (CEBAF) and why the Administration believes it is worthy of Federal support?

Answer: High energy and nuclear physics research tells us that the protons, neutrons, and mesons which make up atomic nuclei are themselves composed of even smaller entities called quarks and gluons. Quarks and gluons are believed to interact according to the laws of Quantum Chromodynamics (QCD). It has therefore become very important in nuclear physics research to understand the extent to which: (1) quarks and gluons influence the structure and interactions of nuclei; (2) QCD is an exact, quantitative theory of the strong nuclear force; and (3) the behavior of quarks changes when the quarks are surrounded by nuclear matter--for example, are new states of nuclear matter created. The Continuous Electron Beam Accelerator Facility (CEBAF), with its continuous beam and its capability of providing electron probes at any energy in the range from 0.5 to 4.0 billion electron volts offers the opportunity to study these questions with an unprecedented degree of precision.

The Administration gives high priority to supporting such forefront basic research activities as nuclear physics at a level which maintains their vitality and world-competitiveness. Federal support of basic nuclear research is this Nation's long term investment in its technological future with nuclear processes--trained manpower, knowledge base, and advanced instrumentation. The research community has determined that the highest priority for new accelerator construction in the United States nuclear physics program is for an electron accelerator with the properties proposed for the Continuous Electron Beam Accelerator Facility.

(2) Question: What are the unique characteristics of the beams which can be provided by CEBAF compared to those of existing accelerators? Why are these characteristics important? What is new about the physics which will be studied at CEBAF?

Answer: The most unique characteristic of the Continuous Electron Beam Accelerator Facility (CEBAF) will be its ability to deliver continuous beam over the energy range 0.5 to 4.0 billion electron volts. Existing electron accelerators, such as the linear accelerator at the Stanford Linear Accelerator Center, have sufficient beam energy but have beam only in the form of very sharp pulses. Some few electron accelerators have continuous beam but much too low beam energy to investigate the ways in which the quarks bound in the neutrons and protons inside nuclei determine the makeup and behavior of nuclei.

Continuous beam is essential to those experiments which require precise timing to identify the results of a collision of an electron with a nucleus. If the incoming electron beam only comes as very sharp pulses, then all collisions take place at essentially the same time. Under such circumstances, our detectors are not able to sort out which fragments came from which collisions. With a continuous beam, our detectors can measure the time spacing of fragments and thereby sort out which fragments came from which collisions. Thus, continuous beam capability greatly increases the information gained from the collisions of electrons with nuclei by allowing us to completely determine the results of a collision--for example, which fragments were knocked out, what were their momenta and energies, what nucleus was left behind, what was its energy, and how much energy and momentum did the electron lose in the collision. With pulsed beams, one or only a few of the above items can be determined.

At energies above the CEBAF maximum energy, experiments are, to a good approximation, only sensitive to effects of electrons scattering from individual quarks within the nuclei. Under these circumstances, nuclei can be described as a loose collection of free quarks. At energies below 1 GeV, electron scattering from nuclei can accurately be described as electrons scattering from the protons, neutrons, and mesons known to be in nuclei. Thus, the 0.5 to 4 billion electron volt capability of CEBAF permits quantitative examination of the transition between two diverse, but likely complementary, descriptions of nuclei.

(3) Question: What is the anticipated life of CEBAF and can you confirm that it is a single purpose machine?

Answer: Because accelerator facilities are continuously upgraded to meet evolving scientific challenges, their useful life is basically determined by their ability to respond to these evolving challenges. The technical design concept for the Continuous Electron Beam Accelerator Facility's (CEBAF) accelerator and experimental facilities is sound and flexible. In its examination of competing accelerator designs, the DOE/NSF Nuclear Science Advisory Committee specifically cited this capability for future expansion as an asset of the CEBAF proposal. Thus, we expect CEBAF to have a long and productive life. Based upon our experience with basic nuclear research facilities, we expect CEBAF to have a useful life of at least 20 to 25 years.

We are building CEBAF as a single-purpose facility dedicated to basic nuclear research. Because the CEBAF design is flexible, it is entirely possible that other scientific opportunities will arise at some future date. As such opportunities arise, the Department will consider their merits and desirability for inclusion in the CEBAF program.

(4) Question: How many accelerators are there in the world which can perform the research which will be done at CEBAF? Would it be cheaper and/or more feasible to modify existing accelerators to perform this work?

Answer: No accelerators exist anywhere in the world that can perform the research which will be done at CEBAF.

The only accelerator which one might consider modifying to perform this work is the linear accelerator at the Stanford Linear Accelerator Center (SLAC). However, this would require disruption of a major effort in the High Energy Physics program and would interrupt construction of the SLAC Linear Collider (SLC). There is also considerable difficulty in finding space for the required pulse stretcher ring and new experimental area without redesign of SLC and/or termination of the Stanford Synchrotron Radiation Laboratory (SSRL), Stanford Positron Electron Accelerator Ring (SPEAR), and Positron Electron Project (PEP) research efforts. Location of the CEBAF project at SLAC is not a reasonable option.

(5) Question: Do we expect competition from other countries in this area, e.g., in Europe or Japan?

Answer: The interesting physics to be done with a high energy, continuous beam electron accelerator has attracted worldwide scientific interest. The Japanese are beginning to discuss the construction of a facility very similar to CEBAF at Tohoku University. The Germans are adding a pulse stretcher ring to an electron accelerator at the University of Bonn. Because of its low beam current, this facility will compete only with CEBAF in the area of tagged photon physics. The CEBAF project is an opportunity for the United States to take a commanding position in an important area of basic physics research.

(6) Question: How important is CEBAF for the future of nuclear physics in the U.S.? Doesn't the unique relationship of the 25 SURA-member universities also make this vital to the training and education of nuclear physicists and to the regaining of U.S. leadership in this field?

Answer: Over the past decade, increasingly sophisticated experimental studies of nuclear properties have shown that the picture of nuclei as a simple collection of nucleons (neutrons and protons) is incomplete. In particular, a more complete nuclear theory must include effects due to excited states of nucleons and definitely the quark substructure of neutrons and protons. Considerable progress is now being made in improving the understanding of nuclei at a more fundamental level. These new insights on nuclear properties suggest a new generation of experiments that will be necessary in order to proceed further. The Continuous Electron Beam Accelerator Facility (CEBAF) facility with its continuous, intense, high energy electron beams will be uniquely positioned to address these new experimental areas and keep the United States in the forefront of a very important and vital area of nuclear physics.

The relationship between CEBAF and the 25 Southeastern Universities Research Association (SURA) member universities will provide a unique opportunity to effectively involve student and faculty members from these institutions in an exciting new area that is truly at the cutting edge of nuclear physics research in the world. The attractiveness of this program should result in an increase in students trained in nuclear physics, attraction of the best and brightest students, and better preparation for their future careers.

(7) Question: What are some of the practical results which have been obtained from other accelerators?

Answer: The variety of practical applications of accelerator beams is kaleidoscopic. They range from the seemingly mundane use of electron beams for sludge disinfection and cellulose degradation to the basic research ideas of inertial fusion and nuclear waste transmutation. Furthermore, the economic consequences of the industries that the accelerators are serving are substantial. The food processing, polymerization, and solid state ion implementation are all multibillion dollar industries at the finished product level.

In medicine and industry, extensive use is made of accelerators. For example, about 1,000 accelerators are now installed in hospitals in the United States. One person in eight at some time in his life will be placed under one of these machines for treatment of cancer. Most of the surgical sutures and disposable medical apparatus in use has been sterilized by exposure to radiation, usually using beams from particle accelerators. In industry, the use of radiation processed materials is widespread and is growing rapidly. A particular example is that of applying insulating coating on wire, where radiation processing allows a better product, costing less and using less volume. Such radiation-processed wire is used, for example, exclusively in the 747 aircraft. Its use is growing rapidly in other applications such as telephone central offices.

One of the most rapidly growing applications of accelerators in industry is the production of integrated circuits. Integrated circuits go through at least one step of ion implantation during their manufacture. Some go through four to six steps. Electron-beam lithography systems can be used to write the circuit patterns on masks, and synchrotron radiation x-rays from electron storage rings can be used to print these circuit patterns on semiconductor wafers. Electron beams can also be used to anneal rapidly the radiation damage that occurs during the ion-implantation process. About 1,000 ion-implantation accelerators are now in use in industry.

In the metallurgical field, ion implantation is being used presently in the research and development phase to reduce friction and to improve wear properties of materials, for hardening, to improve fatigue resistance, corrosion resistance, adhesion of material and for catalysis, and to make superconducting materials. The first two applications cited above could enhance significantly the life of automobile parts and potentially lead to an increase in the fuel economy in current automobiles.

Low current electron, ion, and electromagnetic radiation beams are used for a variety of diagnostics. These range from accelerator dating and electron radiography, resonance neutron radiography, flash x-ray radiography, and to semiconductor analysis and microprobe beams to detect oil and other fuels in underground wells.

In summary, the practical use of accelerators is widespread and has great economic consequences. While the purpose of the CEBAF project is basic research in nuclear physics, it is not inconceivable that the particular accelerator research and development needed to build and operate CEBAF would lead to improvements or new developments in accelerator technology that have practical applications outside of nuclear physics research.

(8) Question: Concern has been expressed by the scientific community that some nuclear physics projects have not been exposed to intensive peer review prior to Congressional consideration. What is the opinion of the nuclear science community about the CEBAF project? Has it been subjected to peer review?

Answer: Peer review of the Continuous Electron Beam Accelerator Facility (CEBAF) project has been extensive and thorough. Through formal studies and public meetings over a five year period, the basic nuclear research community reviewed the scientific need for a high energy, continuous beam electron accelerator facility and concluded that establishment of such a facility is the next logical step for advancement of basic nuclear research in the United States. The DOE/NSF Nuclear Science Advisory Committee's 1979 Long Range Plan for Nuclear Science highlighted the scientific opportunities.

By January 1983, five institutions responded to this identified need and the 1979 Long Range Plan's projection of FY 1985 start of construction by submission of unsolicited proposals; the proposals differed significantly in accelerator concept and other technical parameters. The five institutions were Argonne National Laboratory, University of Illinois at Urbana, Massachusetts Institute of Technology, National Bureau of Standards, and Southeastern Universities Research Association.

The DOE/NSF Nuclear Science Advisory Committee (NSAC) established an ad hoc "Panel on Electron Accelerator Facilities" to recommend the facility or combination of facilities which will best meet the United States needs for basic nuclear research with electromagnetic probes. The Panel, chaired by Professor D. Allan Bromley of Yale University, asked each proposer to provide written critiques of all competing proposals and then respond in public to the written critiques of others. After an intensive series of site visits and public meetings, the Panel reached the following principal recommendation:

> "That the proposal submitted by the Southeastern Universities Research Association (SURA) be accepted and funded for the construction of a new National Electron Accelerator Laboratory (NEAL) centering on a 4 GeV linear accelerator-stretcher ring system capable of delivering intense, high duty factor, electron beams in the energy range from 500 to 4000 MeV."

In April 1983, the parent committee (NSAC) fully endorsed the Panel Report and recommended that it be implemented without delay.

(9) Question: I understand that the Department of Energy/National Science Foundation's Nuclear Science Advisory Committee has prepared a long range plan for nuclear science. Is the CEBAF project included in this long range plan?

Answer: The Continuous Electron Beam Accelerator Facility (CEBAF) and the science to be done with this facility are highlighted in the DOE/NSF Nuclear Science Advisory Committee's (NSAC) "Long Range Plan For Nuclear Science" (December 1983). In the Long Range Plan, NSAC reaffirmed its April 1983 recommendation for the earliest possible start on the construction of CEBAF. The 1983 Long Range Plan specifically calls for start of CEBAF construction in FY 1985.

(10) Question: The Department has sent a $2 million reprogramming request to the Congress which would provide direct support of CEBAF instead of more broadly based accelerator research and development activities. Why is this a good idea? How will the money be used?

Answer: The Continuous Electron Beam Accelerator Facility (CEBAF) is the next logical step for advancement of basic nuclear research in the United States. Thus, research and development (R&D) in support of this project is the Nuclear Physics program's highest priority use of FY 1984 accelerator R&D funds.

The $2.0 million in FY 1984 would be used to develop the technical and manpower base of CEBAF, to conduct detailed design studies of accelerator and beam transport components, and to carry out prototype work on radiofrequency power systems.

(11) Question: Is it unprecedented for the Department of Energy to make Federal research and development funds available for such projects prior to the project receiving Congressional approval through the budget, authorization, or appropriations process? For what specific activities will the funds be used in FY 1984?

Answer: In order that the Department of Energy have an adequate information base for decisions on complex construction projects, research and development (R&D) must be conducted prior to Congressional approval. Such R&D provides the needed information but does not constitute a commitment to proceed with construction. Thus, provision of R&D funds prior to Congressional approval is not at all unprecedented and has proven necessary for most major projects. We are convinced that R&D prior to Congressional approval is essential to proper formulation of the Department's Budget Request to Congress and to prudent management of the Department's construction projects.

Specific FY 1984 activities in support of the Continuous Electron Beam Accelerator Facility (CEBAF) would include: (1) development of CEBAF's scientific and administrative staff; (2) design and optimization studies on the recirculated linear accelerator and pulse stretcher ring which are the technical heart of the CEBAF accelerator; and (3) prototype of key items of equipment such as the radiofrequency systems which will drive the linear accelerator, the resonant cavities which will accelerate the electron beam, the injection and extraction systems for the pulse stretcher storage ring which will smooth the linear accelerator's pulse into a continuous beam, and the bending and focusing magnets which will transport CEBAF's electron beam through the accelerator complex and into experimental research areas.

(12) Question: Does the expenditure of these FY 1984 funds in the amount of $2 million represent an irreversible commitment to the project? Is there any justification or importance that this work be undertaken even if the CEBAF project does not go forward as planned?

Answer: FY 1984 expenditure of $2.0 million for research and development (R&D) in support of the Continuous Electron Beam Accelerator Facility (CEBAF) project does not represent an irreversible commitment to proceed with construction of CEBAF. The FY 1984 activities will provide a valuable information base for the CEBAF project and will permit urgently needed development of CEBAF's technical and administrative infrastructure. None of the FY 1984 activities will alter the proposed site at Newport News, Virginia or result in installation of permanent equipment.

Significant portions of the R&D work planned for FY 1984 are of interest and importance to a broad community of American scientists working to advance accelerator technology for basic research, biomedical, industrial, and defense applications. Specific examples of such general interest include R&D on high power radiofrequency systems and systems for acceleration and transport of high quality, high intensity electron beams. Thus, the planned CEBAF R&D would be valuable even if the CEBAF project did not go forward.

(13) Question: What are the implications for CEBAF if Congress does not give its consent to the FY 1984 reprogramming request?

Answer: The planned research and development (R&D) activities in FY 1984 are essential to orderly building of the Continuous Electron Beam Accelerator Facility's (CEBAF) technical information base, technical and scientific staff, and administrative infrastructure. These people and design data are critical to the CEBAF project. Our ability to determine a reliable project schedule and cost estimate for CEBAF on a schedule compatible with the FY 1986 budget process is based on the use of funds specified in our reprogramming notice for the CEBAF. If funds are not available for this purpose in FY 1984, it will cost a full years delay in the project with an associated increase for the total estimated project cost.

(14) Question: What is the Administration's FY 1985 budget request for CEBAF and how will this be used?

Answer: The FY 1985 Budget Request is $5,000,000 in Operating Expenses to continue and extend research and development (R&D) activities in support of the Continuous Electron Beam Accelerator Facility (CEBAF) construction project and $2,000,000 in Construction funds to initiate the construction project itself. The R&D work will include:

(1) design studies on CEBAF's recirculated electron linear accelerator and pulse stretcher ring;

(2) prototype development of klystrons, modulators, accelerating structures, transmission waveguides, pulse stretcher ring structures, injection and extraction septa for the pulse stretcher ring, and beam switchyard magnets;

(3) optimization studies of experimental buildings and tunnels to house the accelerator complex;

(4) design studies of experimental equipment needed to conduct a research program with CEBAF's unique beams; and

(5) development of CEBAF's technical and administrative team.

Construction activities will include architect/engineering work, detailed design beyond the conceptual level, and preliminary site work including geotechnic studies and renovation of existing buildings to house CEBAF staff.

(15) Question: My understanding of the significance of the FY '85 Administration budget request is that it represents an Administration commitment to CEBAF, subject, of course, to Congressional approval. Is that correct?

Answer: The Department's FY 1985 Budget Request asks authorization and appropriation of funds to initiate construction of the Continuous Electron Beam Accelerator Facility (CEBAF) project. In this sense, the Budget Request does represent a commitment to CEBAF. We are convinced that CEBAF's scientific justification is strong and that its technical feasibility is established.

(16) Question: Could you submit for the record DOE's preliminary operating budget for CEBAF and how this compares with other accelerators?

Upon completion we expect the Continuous Electron Beam Accelerator Facility (CEBAF) to require an annual operating budget of approximately $15 million in FY 1984 dollars for facility operations. Facility operations includes all costs of operation and maintenance of the accelerator complex, permanently installed equipment, and the physical plant--that is, all costs of delivering beam for use by research scientists. In addition, an annual budget of about $5 million will be required for research by CEBAF staff and for plant and instrumentation improvements.

For comparison, the three largest accelerator facilities in the Nuclear Physics program have FY 1984 facility operations budgets of $33.5 million for the Clinton P. Anderson Meson Physics Facility, $17.3 million for the Bevalac, and $5.4 million for the Bates Linear Accelerator Center.

(17) Question: When is CEBAF construction scheduled for completion subject, of course, to Congressional authorization and appropriations?

Answer: Detailed review of the project schedule and cost estimate for the Continuous Electron Beam Accelerator Facility (CEBAF) is in progress. However, we expect that construction will take about five years. Under optimized circumstances which include prompt Congressional approval of the FY 1984 reprogramming request, the first nuclear physics experiment could begin in 1990.

SENATOR JOHN W. WARNER
Senate Subcommittee on Energy Research & Development
March 20, 1984
SD-306

Questions for Dr. Alvin Trivelpiece, Director, Office of Energy Research, U. S. Department of Energy:

1. Can you describe to the Subcommittee in layman's terms the purpose of the Continuous Beam Electron Accelerator Facility (CEBAF) and why the Administration believes it is worthy of Federal support?

2. What are the unique characteristics of the beams which can be provided by CEBAF compared to those of existing accelerators? Why are these characteristics important? What is new about the physics which will be studied at CEBAF?

3. What is the anticipated life of CEBAF and can you confirm that it is a single purpose machine?

4. How many accelerators are there in the world which can perform the research which will be done at CEBAF? Would it be cheaper and/or more feasible to modify existing accelerators to perform this work?

5. Do we expect competition from other countries in this area, e.g., in Europe or Japan?

6. How important is CEBAF for the future of nuclear physics in the U.S.? Doesn't the unique relationship of the 25 SURA-member universities also make this vital to the training and education of nuclear physicists and to the regaining of U.S. leadership in this field?

7. What are some of the practical results which have been obtained from other accelerators?

8. Concern has been expressed by the scientific community that some nuclear physics projects have not been exposed to intensive peer review prior to Congressional consideration. What is the opinion of the nuclear science community about the CEBAF project? Has it been subjected to peer review?

9. I understand that the Department of Energy/National Science Foundation's Nuclear Science Advisory Committee has prepared a long-range plan for nuclear science. Is the CEBAF project included in this long-range plan?

10. The Department has sent a $2 million reprogramming request to the Congress which would provide direct support of CEBAF instead of more broadly based accelerator research and development activities.
    Why is this a good idea?
    How will the money be used?

11. Is it ~~[illegible]~~ unprecedented for the Department of Energy to make Federal research and development funds available for such projects prior to the project receiving Congressional approval through the budget, authorization, or appropriations process? For what activities will the CEBAF funds be used in FY 1984?

12. Does the expenditure of these FY 1984 funds in the amount of $2 million represent an irreversible commitment to the project in the event the Congress decides not to go forward with authorization of the project?

13. What are the implications for CEBAF if Congress does not give its consent to the FY 1984 reprogramming request?

14. What is the Administration's FY 1985 budget request for CEBAF and how will this be used?

15. My understanding of the significance of the FY '85 Administration budget request is that it represents an Administration commitment to CEBAF, subject, of course, to Congressional approval. Is that correct?

16. Could you submit for the record DOE's preliminary operating budget for CEBAF and how this compares with other accelerators?

17. When is CEBAF construction scheduled for completion, subject, of course, to Congressional authorization and appropriations?

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Department of Energy
Washington, D.C. 20585

October 19, 1984

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy Research
and Development
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On March 20, 1984, Dr. Alvin Trivelpiece, Director of the Office of Energy Research, appeared before your Subcommittee to discuss the authorization for energy research.

Following that hearing, you submitted written questions for our response to complete the hearing records. Enclosed are the answers to those questions which also have been sent directly to Senator McClure and the Committee staff.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

bcc: Mr. Al Astrin

POST-HEARING QUESTIONS AND ANSWERS

Relating to the

MARCH 20, 1984, HEARING

Before the

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

Of The

COMMITTEE ON ENERGY AND NATURAL RESOURCES

UNITED STATES SENATE

WITNESS: DR. ALVIN TRIVELPIECE

Several years ago, the Engineering Societies Commission on Energy (ESCOE) recommended that DOE build a multidisciplinary program in Engineering Research to be expanded to a level of at least $50 million by the mid-1980's.

Question: How much of the BES budget will be dedicated to Engineering Research activities for FY85?

Answer: Of the total request for Basic Energy Sciences of $419,530,000 in the FY 1985 President's budget, $7,515,000 was requested for the Engineering Research activity, including $7,115,000 for operating expenses and $400,000 for capital equipment.

As a result of final Congressional action, $13,185,000 was appropriated for Engineering Research, $12,785,000 in operating expenses and $400,000 in capital equipment.

Several years ago, the Engineering Societies Commission on Energy (ESCOE) recommended that DOE build a multidisciplinary program in Engineering Research, to be expanded to a level of at least $50 million by the mid-1980's.

Question: In view of the fact that Engineering Research offers benefits to all areas of energy technology--via a broader understanding of basic energy concepts such as heat transfer, computer-assisted engineering, fracture/failure control, etc.--does DOE have plans to expand this program to the levels recommended by ESCOE?

Answer: Basic Energy Sciences has a plan outlined for orderly expansion of Engineering Research but it is recognized that implementation will depend upon other priority research needs and the overall need to constrain Federal expenditures.

(1) Question: Why is the achievement of ignition and long burn the logical next step in the fusion program?

Answer: Ignition and long burn are connected with plasma self-heating, a phenomenon which greatly enhances the energy gain achievable from a fusion system. The physics of ignition and long burn must be tested and understood before fusion can be considered a practical source of energy. We expect, shortly, to be technically capable of taking this essential step.

(2) Question: Does DOE plan to undertake this step in a timely fashion--or is the idea to wait until an international consortium is formed some time in the future?

Answer: At this stage in the project definition process, it is premature to predict the eventual organizational arrangements. The Department is proceeding with the necessary technical and international preparations in order to make the best decisions on this important step in a timely fashion.

DOE is continuing its technical work to explore the most cost-effective way of approaching ignition and long burn. Following the first design studies last year, it was decided that further work needed to be done on the two options seen as most promising for minimizing cost and successfully achieving the basic scientific objectives. This is now being done by several study groups in this country.

At the same time, the Department has invited the Japanese and Europeans to join our design efforts. The Japanese have accepted and the Europeans are considering possible mechanisms to collaborate. The Department has also made an active start in developing high-level political support for international collaboration on major new fusion facilities through the Versailles Summit Fusion Working Group. The Working Group has begun to identify those major facilities needed to complete the fusion science and technology base, including the ignition and long burn facility.

(3) Question: Is the basic objective of international collaboration to build large fusion projects jointly, or just to cut back on present levels of fusion funding?

Answer: The Department of Energy believes that international collaboration could increase efficiency through reduced redundancy and could accelerate the pace of needed technical development at existing levels of expenditure.

(4) Question: To give some perspective on the likelihood that fusion power will be useful, how would you compare your progress thus far with the progress that still needs to be made?

Answer: Magnetic fusion research has been carried out in the United States for the past thirty years. The early program consisted mainly of small-scale experiments to study basic plasma physics. By the 1970's, the program had progressed to the point where studies of near reactor grade plasmas could be undertaken. In the 1980's, burning plasma experimentation will begin for the first time. In the 1990's, what remains to be done is to understand the physics of ignited, long burning plasmas and to complete the exploration of open and closed magnetic confinement configurations so that optimized magnetic confinement configurations can be designed. In addition we must develop those fusion unique technologies required to make fusion energy useful. This will bring us to the proof of concept point where enough information will be available to make reasonable projections of the economic and environmental potential of fusion.

It is difficult to compare past and expected progress since future progress depends both on technical uncertainty and funding. Within the present technical uncertainty the proof of principle point can be scheduled to some extent because the necessary steps are fairly well specified. At the present world level of support for fusion this point could probably be reached by the turn of the century if significant international collaboration can be established.

(5) Question: What is DOE doing to make sure that the most promising approaches to fusion have a chance to emerge?

Answer: In order to ensure that our research will lead to the most attractive fusion reactor, the Department of Energy maintains a broad fusion program with specific attention to concept improvement. Within the fusion program, reactor systems studies are used to examine the practicality of existing approaches and to identify problem areas. Researchers are encouraged to invent and test ideas that improve fusion attractiveness. Understanding, the basis for invention, is built by continued experimental and theoretical research. International cooperation is used to ensure complementarity of the world's efforts in this area.

This process has already led to inventions such as the tandem mirror, the compact toroid, current drive in tokamaks, and better first-wall materials. We are taking steps to strengthen this process.

(6) Question: At what point is the private sector likely to take over a major share of fusion reactor development?

Answer: The Department of Energy magnetic fusion program is developing the technology and scientific data bases in order to establish the feasibility of fusion as a competitive energy option. As stated in the National Energy Policy Plan issued in October 1983, "Once basic and applied research and development have been accomplished, the pace at which new or alternative technologies are commercialized and marketed will be determined not by the federal government, but by entrepreneurs and consumers. The federal government will continue to emphasize the importance of technology transfer efforts to ensure that the results of publicly supported research and development are available widely and promptly to the marketplace."

APPENDIX IV

Additional Material Submitted for the Record

CELANESE

STATEMENT BY

HARRY W. BUCHANAN

VICE PRESIDENT - CELANESE CORPORATION

SUBMITTED TO THE SENATE

ENERGY RESEARCH AND DEVELOPMENT SUBCOMMITTEE

HEARING ON ENERGY RESEARCH

MARCH 20, 1984, WASHINGTON, D. C.

CHAIRMAN DOMENICI, DISTINGUISHED COMMITTEE MEMBERS, LADIES AND GENTLEMEN.

MY NAME IS HARRY BUCHANAN. I AM VICE PRESIDENT OF CELANESE CORPORATION, A MAJOR PRODUCER OF CHEMICALS, FIBERS AND SPECIALTIES AND THE WORLD'S LARGEST PRODUCER OF METHANOL.

I APPEAR BEFORE YOU TODAY TO REQUEST FEDERAL SUPPORT FOR A LIMITED NUMBER OF DEMONSTRATION PROJECTS TO CONFIRM THE BENEFITS OF METHANOL USED IN STATIONARY POWER GENERATION. I DO SO BECAUSE THE USE OF METHANOL AS A FUEL IN A VARIETY OF APPLICATIONS TO GENERATE POWER APPEARS TO HOLD SUBSTANTIAL ENVIRONMENTAL AND ECONOMIC PROMISE. INDEED, THESE POTENTIAL ADVANTAGES HAVE ALREADY BEEN DEMONSTRATED IN SMALL SCALE TESTS AND IN THE LABORATORY.

BACKGROUND

METHANOL, THE SIMPLEST OF ALL ALCOHOLS, IS ANOTHER NAME FOR METHYL OR WOOD ALCOHOL. THIS DIFFERS FROM ETHANOL, OR ETHYL ALCOHOL, THE MAIN INGREDIENT OF ALCOHOL BEVERAGES. METHANOL HAS BEEN AROUND SINCE THE 1600'S AND WE AT CELANESE HAVE PRODUCED IT SINCE 1946, PRIMARILY FOR USE AS A BASIC INTERMEDIATE CHEMICAL IN THOUSANDS OF PRODUCTS WE ALL USE, SUCH AS PAINTS, SHELLACS, FLOOR COVERINGS, TEXTILES, PLYWOOD, GLUES, COSMETICS AND PHARMACEUTICALS.

MOST OF THE WORLD'S CURRENT METHANOL CAPACITY IS BASED ON SURPLUS NATURAL GAS. HOWEVER, IT CAN ALSO BE PRODUCED FROM A VARIETY OF OTHER RAW MATERIALS, INCLUDING COAL, PETROLEUM AND BIOMASS.

THE PROPERTIES OF METHANOL AS A MOTOR FUEL HAVE LONG BEEN RECOGNIZED AND RECENTLY THE USE OF METHANOL AS A SUPPLEMENT OR REPLACEMENT FOR PETROLEUM-BASED FUELS IN GASOLINE AND DIESEL-POWERED ENGINES HAS BECOME INCREASINGLY ATTRACTIVE. RESULTS SHOW SUBSTANTIAL REDUCTIONS IN HARMFUL ENGINE EMISSIONS AS WELL AS INCREASES IN ENERGY EFFICIENCY MEASURED IN TERMS OF FUEL COST PER MILE. TESTS OF METHANOL USE IN DIESEL-TYPE BUS ENGINES HAVE SHOWN SIMILAR ENCOURAGING RESULTS.

METHANOL IN POWER GENERATION

WHILE THE PROPERTIES OF METHANOL AS A FUEL HAVE LONG BEEN RECOGNIZED, ITS USE AS A FUEL IN UTILITY BOILERS AND TURBINES HAS BECOME INCREASINGLY ATTRACTIVE IN RECENT YEARS AS A RELATIVELY LOW-COST WAY OF REDUCING EMISSION LEVELS. BECAUSE IT BURNS MORE CLEANLY THAN OTHER BOILER FUELS, METHANOL OFFERS SIGNIFICANT ENVIRONMENTAL AND OTHER ADVANTAGES.

THERE ARE TWO MAJOR WAYS TO USE METHANOL AS A FUEL IN THE POWER GENERATION PROCESS.

TURBINES

FIRST, METHANOL CAN BE USED IN TURBINES FOR ELECTRIC UTILITY AND COGENERATION PROJECTS. METHANOL CAN REPLACE STANDARD JET FUEL OR NATURAL GAS AND OFFERS A NUMBER OF SIGNIFICANT BENEFITS:

- REDUCED EMISSIONS: BECAUSE METHANOL BURNS MORE COMPLETELY AND AT LOWER TEMPERATURES THAN PETROLEUM-BASED FUELS, IT PRODUCES MINIMAL PARTICULATES AND NITROGEN OXIDES (12 PPM OF NOx FOR METHANOL AS COMPARED TO 80 - 200 PPM FOR NATURAL GAS OR JET FUEL

ACCORDING TO A RECENT CALIFORNIA ENERGY COMMISSION STUDY). FURTHERMORE, THE COMBUSTION OF METHANOL PRODUCES NO SULFUR DIOXIDE, SO2. METHANOL-FUELED TURBINES ARE THUS BETTER SUITED TO MEET FEDERAL AND STATE AIR-QUALITY OBJECTIVES. FOR MANY UTILITIES THIS FACTOR IS CRITICAL - PARTICULARLY AT A TIME OF GROWING CONCERN ABOUT ACID RAIN.

o REDUCED MAINTENANCE COSTS: NEGLIGIBLE CARBON PARTICULATES AND LOWER METAL TEMPERATURES IN METHANOL-FUELED TURBINES RESULT IN REDUCED ENGINE WEAR AND MAINTENANCE REQUIREMENTS.

o IMPROVED EFFICIENCY: WITH CURRENT ENGINES, THE POWER OUTPUT PER BTU OF FUEL INPUTS IS APPROXIMATELY EQUAL FOR METHANOL AND JET FUEL. IF THE DESIGN OF NEXT-GENERATION ENGINES IS OPTIMIZED FOR METHANOL COMBUSTION CHARACTERISTICS, HOWEVER, AN INCREASE IN EFFICIENCY PER INPUT BTU CAN BE ANTICIPATED.

THESE ADVANTAGES OF METHANOL AS AN INDUSTRIAL TURBINE FUEL WERE PROVEN IN 1979 IN TESTS SPONSORED BY THE ELECTRIC POWER RESEARCH INSTITUTE (EPRI). ADDITIONAL BENEFITS INCLUDE:

o STABLE FUEL COSTS: METHANOL IS PRESENTLY SELLING FOR LESS THAN 50 CENTS PER GALLON IN AREAS OF THE UNITED STATES. ASSUMING A PER GALLON BTU (ENERGY CONTENT) EQUIVALENCY OF APPROXIMATELY 2 TO 1 FOR STANDARD JET FUEL TO METHANOL, METHANOL COMPARES FAVORABLY TO CURRENT PRICES FOR JET FUEL. MOREOVER, ADDITIONAL METHANOL PRODUCTION CAPACITY EXPECTED TO COME ON LINE WITHIN THE NEXT 5 YEARS WILL EXCEED ANTICIPATED DEMAND AND THUS SHOULD

ASSURE A STABLE METHANOL PRICE - IN SHARP CONTRAST TO THE OUTLOOK FOR PETROLEUM-BASED FUELS.

- ENERGY SECURITY: SINCE METHANOL CAN BE PRODUCED FROM A WIDE VARIETY OF FEEDSTOCKS - NATURAL GAS, COAL, LIGNITE, PEAT AND BIOMASS - UTILITIES WILL BE LESS DEPENDENT ON IMPORTED PETROLEUM WITH ITS UNCERTAIN SUPPLY AND PRICE PROSPECTS. EVEN THOUGH IN THE SHORT TERM -- UNTIL DOMESTIC COAL-BASED PLANTS BECOME ECONOMICAL -- MOST METHANOL WILL COME FROM FOREIGN GAS-BASED PLANTS, THESE PLANTS WILL BE LOCATED THROUGHOUT THE WORLD, THUS INTERRUPTION OF SUPPLY FROM ONE AREA WILL NOT DISRUPT THE FLOW OF METHANOL.

OVERFIRING

THE SECOND MAJOR USE OF METHANOL IN A STATIONARY POWER GENERATION IS AS A SECONDARY FUEL IN A PROCESS KNOWN AS "OVERFIRING".

OVERFIRING IS A PROCESS WHERE METHANOL IS BURNED IN SMALL QUANTITIES OVER A FUEL, SUCH AS NORMAL UTILITY-GRADE FUEL OIL. THE NET RESULT IS REDUCED EMISSIONS, PARTICULARLY NITROGEN OXIDES. THERE ARE VARIOUS TECHNICAL REASONS FOR THIS EFFECT: FIRST, METHANOL ITSELF IS NITROGEN AND SULFUR FREE. MORE IMPORTANTLY, SINCE METHANOL BURNS AT A MUCH COOLER TEMPERATURE, IT TENDS TO REDUCE NITROGEN OXIDES.

THE OVERFIRING CONCEPT DIVIDES THE BOILER INTO TWO STAGES -- THE LOWER STAGE BURNING A "DIRTY" FUEL (COAL OR FUEL OIL) AND THE UPPER STAGE BURNING A "CLEAN" FUEL (METHANOL). THIS STAGED COMBUSTION PROCESS SIGNIFICANTLY REDUCES NO_x EMISSIONS BY CONTROLLING THE PEAK TEMPERATURES NORMALLY ACHIEVED IN THE SINGLE STAGE COMBUSTION CYCLE.

THIS TECHNOLOGY HAS IMPORTANT IMPLICATIONS IN AREAS EXPERIENCING SEVERE NOx PROBLEMS. FOR EXAMPLE, NOx EMISSIONS FROM OIL-FIRED UTILITY BOILERS ARE A SERIOUS PROBLEM IN THE SOUTH CALIFORNIA COAST AIR BASIN. A RECENT CALIFORNIA ENERGY COMMISSION CONSULTANT REPORT HAS ESTIMATED, HOWEVER, THAT METHANOL OVERFIRING COULD REDUCE NOx EMISSIONS BY 10,000-15,000 TONS PER DAY (15-25 PERCENT REDUCTION BELOW CURRENT AVERAGE EMISSIONS) IN THE BASIN IF USED AT ALL BOILERS WITH THE REQUIRED CONFIGURATION.

IN ADDITION TO REDUCING NITROGEN OXIDE EMISSIONS, OVERFIRING WITH METHANOL WOULD ALSO REDUCE SULFUR DIOXIDE IN DIRECT PROPORTION TO THE AMOUNT OF FOSSIL FUEL DISPLACED. FOR EXAMPLE, IF METHANOL ACCOUNTED FOR 10% OF THE BOILER FUEL INPUT, SULFUR DIOXIDE EMISSIONS SHOULD ALSO BE REDUCED BY 10%.

THESE EMISSION REDUCTIONS COULD HAVE IMPORTANT LOCAL AS WELL AS INTER-REGIONAL IMPLICATIONS. NOx AND SO2 EMISSIONS HAVE BEEN IDENTIFIED AS A PRECURSOR OF ACID RAIN. METHANOL OVERFIRING HAS THE POTENTIAL FOR REDUCING BOTH NOx AND SO2, AND CAN BE USED IN CONJUNCTION WITH OTHER EMISSION CONTROL TECHNIQUES.

DEMONSTRATION PROJECTS

WHILE THE ENVIRONMENTAL AND ECONOMIC BENEFITS OF METHANOL HAVE BEEN DEMONSTRATED ON A SMALL SCALE, FURTHER TESTS ARE NEEDED, HOWEVER, TO CONFIRM THESE RESULTS IN MEDIUM TO LARGE-SCALE UTILITY AND INDUSTRIAL BOILERS, TURBINES AND COGENERATION PROJECTS. THE PURPOSE OF THESE TESTS WOULD BE TO:

- CONFIRM REDUCTIONS IN NOx AND OTHER HARMFUL EMISSIONS, AND

- DEVELOP TECHNICAL DATA TO ESTABLISH METHANOL EFFICIENCY RATINGS AND DETERMINE THE MOST EFFICIENT OPERATING PROCEDURES.

MR. CHAIRMAN, WE AT CELANESE BELIEVE FOUR LARGE-SCALE DEMONSTRATION PROJECTS ARE NEEDED TO CONFIRM THE POTENTIAL BENEFICIAL ENVIRONMENTAL IMPACT OF METHANOL OVERFIRING IN LARGE UTILITY AND INDUSTRIAL BOILERS.

PROJECT #1 - METHANOL OVERFIRING OVERDISTILLATE FUEL OIL

DISTILLATE FUEL OIL IS A RELATIVELY EXPENSIVE HYDROCARBON FUEL WHICH IS USED IN INTERMEDIATE SIZED POWER PLANTS ALONG THE EAST COAST WHERE VERY LOW SO2 EMISSIONS ARE ESSENTIAL. OVERFIRING WITH 10 - 30% METHANOL CAN FURTHER REDUCE SO2 BY A COMPARABLE AMOUNT WHILE PROVIDING THE ADDED BENEFIT OF SIGNIFICANT NOx IMPROVEMENT. THIS TEST SHOULD BE GIVEN TOP PRIORITY BECAUSE THE PREMIUM FUEL PRICE OF DISTILLATE FUELS WILL MINIMIZE THE ECONOMIC HURDLE FOR METHANOL IN THIS APPLICATION. A 15-20 DAY TEST IS RECOMMENDED IN A MEDIUM SIZED (50 MW) FACILITY TO GATHER SUFFICIENT OPERATIONAL AND ENVIRONMENTAL DATA. THE PROJECT WOULD COST APPROXIMATELY $1.0 MILLION.

PROJECT #2 - METHANOL OVERFIRING OVER RESIDUAL FUEL OIL

THIS TEST WOULD DEMONSTRATE THE COMMERCIAL VIABILITY OF METHANOL OVERFIRING IN LARGE (100+MW) BOILERS. BECAUSE OF THE NUMBER AND SIZE OF THESE PLANTS, THEY REPRESENT A LARGE POTENTIAL FOR NOx REDUCTION. OPERATING EXPERIENCE GAINED WITH THE DISTILLATE DEMONSTRATION SHOULD ALLOW THE TEST TO BE COMPLETED

IN APPROXIMATELY TEN (10) DAYS. THIS DEMONSTRATION IS ESSENTIAL TO GAIN INDUSTRY AND EQUIPMENT MANUFACTURERS' ACCEPTANCE AND TO DEMONSTRATE ECONOMIC AND ENVIRONMENTAL BENEFITS. THE PROJECT WOULD COST APPROXIMATELY $1.2 MILLION.

PROJECT #3 - METHANOL OVERFIRING OVER COAL

SIGNIFICANT ENVIRONMENTAL BENEFITS FOR REDUCED NOx MAY EXIST FOR OVERFIRING COAL WITH METHANOL. THE TEST WOULD BE BEST CONDUCTED IN THE MIDWEST IN A RELATIVELY LARGE BOILER WHERE IT IS NOT OTHERWISE PRACTICAL TO MAKE MAJOR BURNER REVISIONS TO REDUCE NOx. THE TEST IS SLIGHTLY MORE EXPENSIVE AT $1.5 MILLION BECAUSE OF ITS SIZE AS WELL AS THE NEED FOR INSTALLING LARGE VOLUME TEMPORARY FUEL STORAGE. A MINIMUM 10-DAY TEST WILL BE NECESSARY TO PROPERLY SYNCHRONIZE THE COMPLICATED BOILER AND ASSOCIATED SCRUBBING EQUIPMENT FOR COAL.

PROJECT #4 - LABORATORY DEMONSTRATION OF METHANOL FUELED TURBINE

THE MAJOR TURBINE MANUFACTURERS HAVE CONSTRUCTED EXTREMELY SOPHISTICATED DEMONSTRATION LABORATORIES WHERE FULL-SCALE COMBUSTORS FROM A COMMERCIAL 35-100 MW TURBINE CAN BE TESTED. RESULTS FROM THIS TYPE OF LABORATORY ARE FULLY ACCEPTED BY THE POWER INDUSTRY WHILE PROVIDING ADEQUATE INFORMATION TO ALLOW ENVIRONMENTAL EMISSION GUARANTEES BY THE EQUIPMENT MANUFACTURERS. THE ULTRA-LOW NOx POTENTIAL OF THESE TURBINES FUELED WITH METHANOL MUST BE DEMONSTRATED IN THE NEAR FUTURE. THIS INFORMATION IS ESSENTIAL TO MAINTAIN THE ENVIRONMENTAL AND ECONOMIC BENEFITS FROM THE NUMEROUS COGENERATION PROJECTS WHICH HAVE BEEN APPROVED. TOTAL COSTS OF THIS DEMONSTRATION WILL BE APPROXIMATELY $300,000.

IN CONCLUSION, WE AT CELANESE BELIEVE THAT SUPPORT BY THE FEDERAL GOVERNMENT OF THE PROJECTS I HAVE DESCRIBED WILL FOCUS NATIONAL ATTENTION ON THE NEED TO DEVELOP CLEAN-BURNING ALTERNATE ENERGY. IT WOULD ALSO SPUR ADDITIONAL JOINT "PRIVATE/PUBLIC SECTOR" TESTING. ALL EVIDENCE SHOWS THAT THE MOST PROMISING ENVIRONMENTALLY CLEAN FUEL OF THE FUTURE IS METHANOL. IT'S HERE TODAY! THANK YOU.

A SUMMARY OF ESTIMATED COSTS FOR EACH OF THESE DEMONSTRATIONS IS PROVIDED IN A CHART WHICH IS ATTACHED TO THIS STATEMENT.

I'LL BE HAPPY TO ANSWER ANY QUESTIONS.

ATTACHMENT

Methanol Fuel Stationary Tests

Cost Estimate, M$

Test Description	Design Engineering and reporting	Equipment & storage costs	Fuel Costs	Total Cost
Overfiring Distillate Oil	100	650	250(1)	1,000
Overfiring Residual Oil	150	750	300(2)	1,200
Overfiring Coal	200	900	400	1,500
Turbine Fuel Laboratory Test	100	100	100	300

(1) Assumes net fuel for overfiring tests with methanol costing $200-400/MM Btu more than fuel oil depending on location and type of fuel replaced.

(2) The shorter test offsets the greater fuel penalty.

NOTE: Specific costs may vary 20-30% depending upon the actual location, equipment configuration, and operating procedures.

STATEMENT

on the

FY 1985 MAGNETIC FUSION ENERGY BUDGET

for the

ENERGY RESEARCH & DEVELOPMENT SUBCOMMITTEE

SENATE ENERGY COMMITTEE

Submitted By

Dr. Tihiro Ohkawa
Vice President, Fusion and Advanced Technology

GA Technologies Inc.

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March 20, 1984

Chairman Domenici, Members of the Committee, thank you for providing GA with the opportunity to submit written testimony on the Fiscal Year 1985 Magnetic Fusion Energy budget. More importantly, thank you for your support of the fusion program in general and of GA in particular.

GA Technologies has the broadest involvement in fusion research of any industrial concern in the world. We have been a contributor in the three decade-long progression of the fusion program from primitive benchtop experiments to sophisticated devices utilizing advanced technology and approaching reactor plasma conditions. Based on the wisdom gained from participating in this progression, I wish to state my personal view of the proper direction for the magnetic fusion program.

The top priority is an unequivocal demonstration that fusion is here. The key to such a demonstration is producing a fusion fire, an ingnited plasma. The tokamak program has established the scientific basis to proceed with construction of such a device - the Tokamak Fusion Core Experiment (TFCX). In parallel with TFCX, we must vigorously pursue a variety of confinement approaches (including the tokamak) that hold the most promise for attractive reactor embodiments. This strategy of pushing ahead with a demonstration of fusion in concert with evolving the reactor concept is in complete accord with the recommendations of the Energy Research Advisory Board (ERAB) and the Magnetic Fusion Advisory Committee (MFAC).

The pace of progress in magnetic fusion research has continued to accelerate. In the tokamak area, the past 18 months has witnessed a number of important programmatic and conceptual milestones, most notably

1. Achievement of quality of confinement sufficient for ignition.
2. Demonstration (at GA) that acceptable power densities are attainable.
3. Production of plasma current via radio frequency techniques alone.
4. Favorable confinement trends in early results from the new generation of very large tokamaks.

These exciting advances have served to crystallize community support for proceeding with TFCX. Indeed, all that we have learned in recent years has increased our confidence level in the ability to design and execute an ignition-level project. Moreover, the plans for existing devices in the coming 12-24 months will provide natural checkpoints for determining the design specifics. The GA program will play an important role in providing this design input. Our principal vehicle, the Doublet III tokamak, will be upgraded through the installation of a large dee vacuum chamber that provides an ideal test bed for simulation of TFCX.

In fact, the GA program in many respects reflects the direction the national program is taking. Our largest program element is Doublet III, a tokamak that forms an integral part of the preparation for TFCX. But we also have a major involvement in alternate concept research through the OHTE program, another confinement scheme that has had major recent laboratory successes. While this approach is much less developed than the tokamak, it is so replete with promise that major corporations have chosen to support this venture entirely with private funding. Such a commitment, which is only possible because of the progress being made in parallel via federal funding, is indicative of the richness of opportunity in the quest for fusion power.

OHTE is one example of the innovation that has characterized the history of fusion research. The innovations of the past decade - plasma shaping, current drive, methods of controlling the plasma edge - form the basis for TFCX design. I fully expect that the new ideas spawned from the basic research underway now throughout the community will dominate our concept of a fusion reactor a decade hence.

My belief is that the only way to fully assess fusion's prospects is to build a fusion engine and see how it performs. Because of the progress in tokamak research, we know enough now to make TFCX a success. In conjunction with a vigorous program to search for the optimal reactor embodiment, TFCX will in turn teach us enough to structure the transition of fusion to the commercial stage. I urge you to provide us the support we need to build upon our successes and to proceed with the TFCX.

Budget guidance for FY 1985 and beyond does not provide the enhanced funding that we would prefer to see as an accompaniment to proceeding with TFCX. Carrying out the TFCX project within a level budget will cause some erosion of the base program needed to maintain the long term schedule for fusion power.

Mobilizing the human, fiscal, and hardware resources of the fusion program to efficiently support the TFCX initiative will take time. I wish to request a $10M increment to the Congressional Budget submitted from the Department of Energy to facilitate this transition period. Of these funds, $5M will be ued to support the industrial teams participating in the design effort. Speaking as a representative of a number of industrial concerns actively involved in fusion R&D, I wish to convey how anxious we are to participate in the formative stages of the project. The remaining $5M will be applied toward research and development in the long lead time component development areas, specifically auxiliary heating and pellet injection. Initiating the component development work now will permit proof-testing these concepts on existing devices.

In closing, I wish to add a few remarks on the subject of international cooperation. The Japanese government entered into an agreement for joint research on the Doublet III facility. This is the largest cooperative scientific endeavor the US has yet embarked upon. Its success is owing to two perceptions in the negotiation stage: first, that each side would benefit and second, that the program in question was a firm commitment of the host government. I conclude that while international cooperation would certainly be advantageous for TFCX, it will only happen if it is clear that the project will be undertaken regardless of the outcome of the negotiation process. Hence, we should explore the cooperation route in parallel with getting the project underway.

Your continued strong support of the magnetic fusion program is greatly appreciated.

STATEMENT OF THE
SOCIETY OF NUCLEAR MEDICINE
AND
AMERICAN COLLEGE OF NUCLEAR PHYSICIANS
FOR THE
SENATE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
OF THE
SENATE ENERGY AND NATURAL RESOURCES COMMITTEE
CONCERNING THE
DEPARTMENT OF ENERGY'S FISCAL YEAR 1985 BUDGET

MARCH 20, 1984

The Nuclear Medicine community appreciates this opportunity to provide information concerning the important and vital contribution made by the Nuclear Medicine Applications portion of the Department of Energy's Biological and Environmental Research Program to the clinical practice of Nuclear Medicine.

This statement is being submitted on behalf of the Society of Nuclear Medicine and the American College of Nuclear Physicians. Both organizations strongly support the need for continued funding of Nuclear Medicine research through DOE. The College is a professional organization representing more than 1,200 physicians and scientists actively engaged in the practice of Nuclear Medicine. The Society of Nuclear Medicine is a scientific organization of 10,000 members including physicians, physicists, chemists, radiopharmacists, Nuclear Medicine technologists, and other professionals engaged in the medical use of radioactive materials. The combined membership of these two organizations constitutes the Nuclear Medicine community of this country.

The College and Society are fully cognizant of the severe budget constraints that the Congress, and your Subcommittee, must work under in addressing FY 85 budget needs. However, it has been our experience that in the field of Nuclear Medicine the application of basic research activities leads to extraordinary health benefits and cost savings for the American public. Past research resulting from DOE's Nuclear Medicine Applications Program, designed to enhance the applications of both radioactive and stable isotopes has produced benefits which we will outline.

WHAT IS NUCLEAR MEDICINE TODAY?

In a typical Nuclear Medicine procedure, the imaging study, a very small amount of a radioactive preparation is administered by injection. This tracer may be designed specifically to concentrate in one body organ, or to be metabolized or removed from the body by a particular route. Some radioactive drugs are designed to concentrate only in abnormal tissue such as cancer cells or compromised heart muscle. Sophisticated instrumentation records the transit and images the distribution of the radioactive preparation in the body. Data derived from the examination may also be processed by computer, producing improved images and quantitative information about organ function. Organ systems, even specific clusters of cells, routinely examined in this fashion include brain, lungs, liver, kidneys, bone, thyroid, pancreas, heart, and major blood vessels.

If the study indicates that no abnormality is present, the patient can be reassured, possibly even discharged from the hospital, and the physician can turn his attention elsewhere. If the study identifies a disease process, then the physician can proceed to the next phase of diagnosis or treatment. It should be emphasized that Nuclear Medicine diagnostic procedures are safe and painless for the patient.

Diagnostic in vitro examinations encompass certain tests in which no radioactive material is administered to the patient. Instead, a sample of some body fluid, usually blood, is collected from the patient and reacted with a radioactive reagent in a test tube. These tests are used to determine the presence of hepatitis, pregnancy, and cancer antigens, to determine the precise concentration of various hormones, vitamins and drugs, and to identify pollutants or other toxic materials in the environment. Radioimmunoassay techniques permit early discovery of tumors and matastases before they become evident clinically.

Approximately 120 million Nuclear Medicine procedures are performed each year in hospitals and outpatient facilities - - on the average two on every patient admitted.

HOW EFFECTIVE ARE NUCLEAR MEDICINE PROCEDURES?

The ACNP and SNM believe that Nuclear Medicine procedures, by improving and streamlining the diagnostic process, (1) reduce total health care expense, hospitalization time, and patient suffering by rapidly directing patient treatment and (2) provide in many areas more useful information about the patient's problems than that available from other diagnostic modalities, many of which are much more costly. Because Nuclear Medicine procedures can be used to study rapidly changing body processes, as in heart and kidney, they tell us how the body functions, as opposed to other imaging procedures such as radiography which reveal only anatomic information. With the advent of the new Medicare Prospective Payment System and other emerging cost containment methods, the cost effectiveness of most medical procedures will be carefully scrutinized. We are confident that Nuclear Medicine will fare well under this scrutiny.

Nuclear Medicine techniques are especially versatile for basic research in the chemical, biological, and physical sciences. Since techniques are similar, data in these areas are easily expanded into clinical research allowing rapid application of information from the research laboratory to clinical practice. The following are a few of many such applications, demonstrating the importance of a continuing high level of research:

(A) CARDIAC NUCLEAR IMAGING

One of the most dramatic examples of the rapid transfer research developments to the hospital is the noninvasive study of the human heart. Heart attacks kill approximately 700,000 people annually and are the leading cause of death in the United States. Almost 300,000 individuals suffer their first heart attack without prior knowledge of having significant coronary disease. Early identification of persons at risk had heretofore been particularly difficult. Nuclear diagnostic techniques developed and applied within the past four years are significantly more sensitive and less risky in identifying individuals with diseased coronary arteries (hence at risk) than are other diagnostic methods such as electrocardiographic stress testing, and much less expensive and hazardous than coronary arteriography. Positron emission tomography, developed in large part by DOE laboratories, is the only method of measuring the metabolic activity of heart muscle in a non-invasive manner.

These newly developed nuclear diagnostic methods are being applied with increasing frequency in outpatient facilities where men and women in certain high risk categories can be screened for heart disease. Such techniques are also being used to assess the extent of damage after heart attacks have occurred. Marked reduction in costs is accomplished by screening patients with these procedures on an outpatient basis, reserving the expense of hospitalization and cardiac catherterization for those patients whose findings indicate the need for further studies. Additional savings result when patients requiring further hospitalization can be transferred out of the costly intenstive care units.

(B) CANCER PATIENT EVALUATION

Another example is found in cancer-related studies. The major emphasis of Nuclear Medicine in the field of cancer has moved from the therapeutic use of radioactive materials to the use of improved imaging modalities which permit earlier detection and better staging of cancers. In addition, there is growing use of Nuclear Medicine in monitoring the therapy of cancer and early discovery of recurrent or disseminated cancer. Despite this progress, present technology cannot pinpoint very small growths and often cannot determine their nature. Therefore, these techniques need to be improved by development of more specific radioactive drugs, by exploration of more sophisticated immunologic and biochemical methodology, and by development of instruments with better spatial resolution (such as that offered by emission tomographic techniques). Research with radiolabled monoclonal antibodies is an example of a promising new approach that is being pursued.

Nuclear Medicine procedures also provide a most important means of monitoring treatment in the cancer patient, by providing information on progression or regression of the tumor. This information allows the clinician to continue or modify treatment accordingly. Among the most serious problems in cancer chemotherapy are the serious side effects that anticancer drugs produce. Such effects can often be more efficiently monitored through the use of Nuclear Medicine procedures. For example, certain cancer drugs can adversely affect the heart muscle. Nuclear Medicine methods provide a guide to therapy whereby this toxicity and the possibility of drug induced heart failure can be avoided.

(C) PATIENT TREATMENT

1. Treatment of Cancer

   Improvements in cancer therapy have come about by the development of improved radiotherapy beams, better localization of the tumor, computer-aided treatment planning, and new chemotherapy agents and regimens. Further benefits derived from the use of charged heavy particles (protons, alpha particles, and mesons) arise from better dose distributions, and impressive advantages already have been demonstrated in the treatment of benign and malignant growths in the brain. Reduced morbidity and mortality and decreased cost to the patient are achieved from these procedures. The facilities needed for these treatments are only present at DOE National Laboratories and major research centers. Additional support is needed to develop specialized low cost accelerators dedicated for medical purposes.

2. Heavy Ion Therapy

Heavy ions are being used at the Lawrence Berkeley Laboratory for the treatment of blood vessel malformations in the brain. Approximately 10,000 Americans per year are found to have this condition which is not readily treatable surgically. These patients benefit from this new mode of treatment which has been developed with DOE support in the last two years. This program also has proceeded to the treatment of other tumors, with major new successes in the treatment of ocular and spinal cord tumors.

3. Labeled Monocolonal Antibodies

Labeled monocolonal antibodies offer the promise for the treatment of certain cancers using the specificity of the antibodies to the tumor as a way of localizing the dose. These studies in many instances are provided through collaboration between National Laboratories (Lawrence Berkeley Laboratory, Brookhaven, Los Alamos, Oak Ridge), and Universities (George Washington University, Washington University in St. Louis, University of California at Davis, University of Kentucky, and others).

(D) INSTRUMENTATION DEVELOPMENT

Important new knowledge of brain bunction in health and disease has been obtained by the use of positron emission tomography (PET) imaging. PET systems have improved in performances significantly, but resolution is still lower than can be achieved ultimately and cost is still too high for all but a few research centers. Further improvements in instrumentation are needed to resolve small structures of importance. Developments in high energy physics instrumentation need to be adapted to medical application to achieve optimal resolution and diminished cost. A five-fold decrease in cost seems realistically achievable with a two - to three - fold improvement in resolution, given funding for instrumentation support for medical applications at the National Laboratories for the transfer of this important technology.

Since PET technology requires an on-site cyclotron and is expensive, the potential of single photon emission tomography (SPECT) is being widely explored. If perfected, this technology would be readily available widely without much additional expense, since the basic instruments are already present in most Nuclear Medicine departments. Research for instrument modification and SPECT radiopharmaceutical development is heavily dependent on DOE support.

(E) PEDIATRIC NUCLEAR MEDICINE

Further examples of the improvement in health care from research and development in Nuclear medical techniques are in the area of pediatric medicine. A Nuclear Medicine bone scan is the most effective technique for the early differentiation of bone infection from soft-tissue infection, disorders that are clinically similar but markedly different in treatment and outcome. A Nuclear Medicine liver excretion study is the only method short of exploratory surgery to differentiate blocked bile ducts from liver inflammation in jaundiced newborn infants, who tolerate surgery very poorly.

There has been much recent research emphasis on the production and diagnostic use of short-lived radionuclides. An example is the cooperative effort between Oak Ridge National Laboratory in Tennessee and Children's Hospital in Boston, which was initiated to produce an Osmium-191/Iridium-191m generator. Osmium-191, with a half-life of 15.4 days, products Iridium-191m, which has a half-life of 4.96 seconds.

This short-lived isotope permits repeated determination of cardiac function with exercise or administration of drugs, particularly important in pediatrics because children change for better or worse much faster than adults, making speed in diagnosis critical. Isotopes with short half-lives deliver much lower radiation doses to patients.

(c) AGING AND ATHEROSCLEROSIS

Nuclear Medicine provides noninvasive methods of studying changes of brain metabolism during normal aging. Of significance are the initial results of DOE supported research on Alzheimer's disease, reported just this year. A group of collaborating investigators supported in the main by the Department of Energy's high technology program on nuclear instrumentation and the National Institutes of Health have discovered an extremely vital piece of information with regard to Alzheimer's disease. A pattern of decreased glucose metabolism occurs in specific areas of the brain in patients with this disease. These patterns are distinctive, particularly when compared to the patterns seen in normal aged matched individuals as well as individuals with other forms of dementia. If these observations are confirmed, it may be possible, for the first time, to identify patients with Alzheimer's disease. Precise diagnosis of a disease must be possible before effective treatment can be developed.

In addition, through investigations of the distribution of chemicals involved in neural transmission, Nuclear Medicine studies have provided for the first time a tool for understanding whether there are changes in neural transmission associated with aging.

Atherosclerosis research has benefitted in two major areas. It is now possible using Nuclear Medicine advances in positron emission tomography and single photon tomography to evaluate the efficacy of methods of treatment for stroke and heart attacks. These advances come from developments in instrumentation physics provided through the unique capabilities of the National Labs and from new radiopharmaceuticals. For example, at present, Brookhaven National Laboratory produces the purest form of the tracer Iodine-123 for use in synthesizing compounds to study stroke. The major, and for practical purposes only, source of Strontium-82 which is needed for protection of Rubidium-82 used in imaging blood flow of the heart muscle is at Los Alamos National Laboratory. A super high resolution positron emission tomograph which will provide the capabilities for the time to evaluate metabolic activity in small regions of the brain and heart is being developed by the Department of Energy at the Lawrence Berkely Lab (Donner Lab).

(G) MENTAL DISORDERS

One of the major contributions made through collaborative work between National Labs and Universities, e.g., New York University, Cornell, and Brookhaven, is the investigation of the metabolic patterns of the brain in schizophrenia. This is still an area of great controversy; however, for the first time in centuries there appears to be a quantitative tool whereby this disorder can be studied in a systematic fashion using noninvasive techniques.

The facilities and skills at the DOE supported National Laboratories are of prime importance for the development of these procedures and for their dissemination to the user community in medical centers throughout the country.

SUMMARY OF PROMISING AREAS OF RESEARCH

a) Expanded radioisotope production efforts: to provide new radioactive materials from accelerators as well as to increase the supply of current radionuclides for radiopharmaceutical development and clinical feasibility studies.

b) Radiopharmaceutical research: to improve understanding of drug distribution and mechanisms of drug action; to increase the specificity of tracer uptake; to measure the effects on biodistribution caused by particular chemical groups; to identify and characterize drug interactions; to address problems related to biological effects of environmental pollutants; to achieve reductions in patient radiation dose by developing radiolabeled drugs having more desirable properties.

c) Stable (non-radioactive) isotope tracer development: to expand the spectrum of metabolically active substances labeled with enriched stable isotopes of carbon, oxygen, and nitrogen; to study a wider variety of clinical applications of stable tracer technology.

d) Nuclear Medicine instrumentation: to improve design and efficiency of detectors; to continue development of emission and single photon emission tomography, nuclear magnetic resonance analysis, and computer-assisted diagnosis.

SPECIAL CONCERNS

The ACNP and the SNM do request the Committee to consider three specific areas of concern regarding the Nuclear Medicine Applications portion of Biological and Environmental Research Program:

First, during the past several fiscal years, there has been an inadequate percentage of the Nuclear Medicine Applications budget allocated for capital equipment needs. In comparably high technology research areas such as high and medium energy physics and nuclear chemistry, the normal percentage of capital equipment funds to operating funds is in the range of 10-20 percent. Nuclear Medicine research requires equipment and instrumentation of similar cost and sophistication; however, during the past several fiscal years, the percentage allocated for capital equipment in Nuclear Medicine research has been in the range of four percent of operating costs. The consequence of these past allocations is the present need for upgrading of equipment for the basic DOE Nuclear Medicine research program in all of the laboratory facilities.

This problem is not amenable to a one-time remedy, particularly in view of current budget constraints, but instead will require several years of attention. Therefore, we urge the Committee to consider appropriate means for assisting DOE in the identification of past deficiencies and future needs in this vitally important area. We feel this should include a policy that will provide adequate funding for capital equipment for the Nuclear Medicine research program, with an annual increase of at least 20 percent.

Second, there is a problem associated with the stable isotope production program that concerns us. Oak Ridge National Laborabory (ORNL) is the sole domestic source of certain stable isotopes necessary for the production of radioisotopes used in medical research, diagnosis and treatment. For example, ORNL separates and distributes stable Thallium-203 for production of Tallium-201 in heart studies and stable Tellurium-124 for production of Iodine-123, a short-lived isotope which reduces pateint radiation dose and markedly improves image quality as compared with other isotopes of Iodine. Under the existing budget, only two of the four banks of separators at ORNL can be operated. Serious consideration must be given to providing sufficient funds to permit the operation of all four separators so that present needs can be met, depleted inventories reestablished, and the increasing number of research and industrial cyclotrons supplied by these separators allowed to keep pace with increasing demand from the medical community. The products of these separations are also essential to important basic research in the non-medical sciences of physics, chemistry and geology.

Third, while we fully understand the basis for incorporation of the Nuclear Medicine Applications and Live Sciences Research budgets into the significantly larger Bilogical and Environmental Research budget category, we respectfully request that the Committee clearly identify seperately that portion of the Biological and Environmental Research appropriation to be devoted to the Nuclear Medicine Applications Program.

We sincerely thank the Subcommittee for the opportunity to submit this testimony and are prepared to answer any questions that may arise.

Respectfully,

Schuyler V. Hilts, M.D. President American College of Nuclear Physicians	Merle K. Loken, M.D., Ph.D. President Society of Nuclear Medicine

3/27/84

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1985

THURSDAY, MARCH 22, 1984

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:35 p.m., in room SD-366, Dirksen Office Building, Hon. Pete V. Domenici, presiding.

Present: Senators Domenici, Evans, Johnston, and Ford.

Also present: Paul Gilman, professional staff member; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator DOMENICI. Good afternoon. Today this subcommittee will review the 1985 budget request for nuclear energy.

We have with us Dr. Shelby Brewer, the Assistant Secretary for Nuclear Energy Programs over at the Department of Energy, and we have Mr. Michael Lawrence, Acting Director of Civilian Waste Activity Programs at DOE.

Following the testimony, we will hear from some public witnesses on this subject. I will say to the public witnesses, if they're here, we do have a joint session at—which we leave at 3:10 to hear the leader of France. And I think I'm going to go. I don't know if the other Senators, if anyone would want to preside while that's going on. If not, we will try to come back when it's over and hear from you.

Let's proceed, Mr. Secretary.

STATEMENT OF SHELBY T. BREWER, ASSISTANT SECRETARY, NUCLEAR ENERGY, DEPARTMENT OF ENERGY

Mr. BREWER. Thank you, Mr. Chairman. I'll be very brief.

Quite a lot has occurred since we met last year. You're aware of the troubled plants in this country: Marble Hill, Diablo Canyon, Seabrook. All of these underscore the urgent need for nuclear licensing reform.

Some have suggested that the nuclear industry is dead or is dying, and that nuclear power is a failed option. I don't believe that. We have over 80 plants operating in this country, providing 13 percent of our Nation's power. We have more reactor experience than any other country.

You will note, Mr. Chairman, in the budget submission we are giving specific attention to the high temperature gas reactor this year.

We faced this past year a crisis in uranium enrichment. We have now turned that situation around, and I'm confident that we are nearing the end of this problem through the issuance of the new utility services contract. To date, over 55 percent of our customers have indicated they will convert to the new contract.

Mr. Chairman, this concludes my statement.

Senator **Domenici**. We're going to make your full statement a part of the record.

[The prepared statement of Mr. Brewer follows:]

STATEMENT OF
SHELBY T. BREWER
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
DEPARTMENT OF ENERGY
BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
UNITED STATES SENATE
MARCH 22, 1984

Mr. Chairman and Members of the Subcommittee, I am pleased to be here today to discuss the Department of Energy budget for nuclear fission energy programs. Our Energy Supply research and development funding request for FY 1985 is $590.4 million in budget authority as compared to the $663.3 million appropriated in FY 1984. The funds requested are distributed among the major program elements as indicated in the following table:

Program Element	FY 1984 ($ in Millions)	FY 1985
Converter Reactor Systems	$ 92.7	$ 83.5
Breeder Reactor Systems	423.2[a]	308.1
Advanced Nuclear Systems	34.1	33.5
Remedial Actions	99.0	152.0
Nuclear Waste Technology	14.3	13.3
Subtotal Energy Supply R&D	663.3	590.4
Uranium Enrichment	2,193.8[b]	1,675.3
Uranium Enrichment Revenues	-2,105.0	-1,675.3
Subtotal (Net)	$ 88.8	$ 0
Total	$ 752.1	$ 590.4

[a] Includes $40 million transferred from the Uranium Enrichment Program for Clinch River Breeder Reactor termination.

[b] Includes $130 million of deferred funding; excludes $40 million transferred for Clinch River Breeder Reactor termination.

Note: The FY 1984 numbers reflect comparabilities.

Before describing these program elements in detail, I will comment briefly on a number of the external factors that have influenced the preparation of our FY 1985 budget.

The past year has been a complex mixture of successes and disappointments for nuclear energy. We have a President who strongly supports nuclear power and recognizes it as an essential element of a balanced energy supply for the future. In 1983, three new nuclear powerplants achieved commercial operation status, raising the annual output of nuclear-generated electricity to almost 300 billion kilowatt-hours, or about 13 percent of our total electrical generation. Nuclear power continues to provide us with safe, clean energy. The economics of plants operating today are on a par with coal, and substantially more favorable than oil or gas. In spite of this impressive performance, nuclear power is not considered an attractive investment by the electric utility industry. Six plants were cancelled in 1983 -- and four more were either cancelled or indefinitely delayed in January of this year. In addition, no new plants have been ordered since 1978. The fact that this disturbing situation is the result of complex and interrelated economic, regulatory, and institutional problems, rather than any deficiency in the technology, is of little practical consequence. While we are seeing a daily improvement in economic indicators that gives us some hope of renewed investment, as yet that hope has not materialized. To dwell on our defeats, however, is counterproductive. We must now turn to new and alternative strategies for ensuring future nuclear vitality. With this challenge in mind, we have formulated the budget request that we are presenting to you today.

Our proposed programs are supportive of the President's nuclear policies and are entirely consistent with the Department's National Energy Policy Plan (NEPP-IV) sent to Congress last fall. Our goal of ensuring that nuclear power remains a viable option for a balanced and diverse energy resource base contributes to the national goal of fostering an adequate supply of energy at reasonable costs. Important elements of this balanced system are new advanced technologies to provide adequate energy supplies well into the future. Our programs support the policy of minimizing Federal control and involvement in energy markets. Accordingly, all nuclear research and development will be conducted with an eye to transferring the technology to the private sector for demonstration and deployment as soon as is feasible.

We interpret our role as one of extending the nuclear technological horizon in order to create private sector opportunities for commercializing and marketing those concepts that best meet their needs. In addition, we must continue to fulfill the Federal responsibility for maintaining public health and safety and environmental quality in regard to all nuclear-related activities under our jurisdiction.

We have been keenly aware of the institutional problems that confront the current generation of commercial nuclear power -- light-water reactors. The utilities are not committing capital for the construction of any large powerplants, be they nuclear or coal. Unless and until the fundamental problems that result in unacceptable business risk for the utilities are resolved, there will be few if any orders for new, large powerplants of any kind. The consequence of this is electricity costs that are higher than necessary. For industries where electricity costs make up a substantial portion of their business expenses, such as the aluminum industry, this will result in a serious deterioration of their competitive position in the world market and/or the necessity to expand outside the United States with the attendant loss of jobs in this country.

In some areas, utilities are turning to imports of Canadian nuclear electricity as a near-term expedient to reduce their supply costs. Unfortunately, these solutions reflect our inability as a Nation to solve the fundamental problems confronting the electric utility and nuclear industries today. The commercial nuclear power industry in the United States has taken over a quarter of a century and hundreds of billions of dollars to develop. The Nation must consider seriously the effects that would be attendant upon a continued decline and ultimate demise of this industry.

We have analyzed carefully what steps the Federal Government could and should take to effect solutions that would renew confidence in the nuclear option. A priority emphasis will be placed on continued efforts to encourage passage of nuclear licensing reform legislation. The outdated system currently in use was established 25 years ago. A more predictable process is badly needed to ensure efficient licensing and regulation of the plants already in operation or under construction. It is also a prerequisite for a renewal of utility interest in nuclear investment.

On March 18, 1983, DOE sent to Congress its legislative proposal for improving the regulatory and licensing process for nuclear powerplants, with the following three major objectives:

- To provide for continued improvement in the safety of nuclear powerplants
- To improve the effectiveness of public participation
- To provide a more stable and predictable licensing process.

The NRC also submitted a proposal for licensing and regulatory reform. It is important to note that the Administration's proposals are not an attempt to resolve the debate over the need for nuclear power or its desirability when compared with other energy sources. Nuclear licensing reform is a necessary but not sufficient condition for new nuclear powerplant orders. The proper role of nuclear power in the Nation's energy future should be decided by the free market system, but it cannot receive proper consideration if we continue with an inefficient and outmoded Federal regulatory process.

Mr. Chairman, I would now like to highlight some of the major elements of our FY 1985 nuclear program.

Converter Reactors

In addition to our effort to contribute to the resolution of problems confronting the nuclear industry, in FY 1985 the Department will also be evaluating alternative, advanced design concepts. There is a need to develop the technology for reactors that have less complicated safety systems and better economics, thereby increasing both public and utility confidence. We will also be evaluating the potential of small High-Temperature Gas Reactors for unique domestic and international markets. Where appropriate, we will conduct collaborative programs with Japan and the Federal Republic of Germany. This is one of a number of areas in which we will be pursuing increased international cooperation in technology development.

The Converter Reactor Program also supports the cleanup at TMI. As you know, DOE has limited its effort to performing generic research and development that can contribute substantially to our knowledge of both accident recovery and accident prevention. We believe that important technical progress is being made, but activity is impeded by a shortfall of required funds. The nuclear industry, through the Edison Electric Institute, pledged support for the cleanup, with a target of $150 million. At least $100 million is required before funds can be transferred to General Public Utilities, the TMI owner. To date, only $80 million has been pledged, but a recent favorable ruling by the Internal Revenue Service, which makes pledges tax deductible, is expected to generate additional funds. Although the DOE commitment to the TMI cleanup remains firm, it now appears that our FY 1984 and 1985 expenditures will be less than planned, due to slower than expected progress by the other parties involved in the effort.

Breeder Reactor Systems

Our FY 1985 request for Breeder Reactor Systems reflects the major restructuring that has taken place in the breeder program. While our overall goal remains the same -- to develop the technology for introduction of a marketable breeder reactor by the private sector early in the next century -- our strategy has changed. Last year, our activities were project-oriented, based around Clinch River construction and operation. With the termination of Clinch River, our program focus has shifted to resolving those technical issues that stand in the way of commercialization by industry. We understand breeder technology; the United States still has the greatest technological base for breeders in the world, and we know it will work. The challenge now is to make it commercially viable. That can be done only if the cost of the product is brought in line with the cost of its competition and if it can be made attractive (i.e., safe and reliable) to both the customer and the public. And this challenge must be faced in light of new realities regarding Federal support for energy development. While the Federal Government will continue to be needed to provide certain institutional and financial support, large capital outlays are not practical or appropriate in the budgetary and political environment we face. Nor are they likely to be practical for some time to come.

The challenge, then, is to develop a breeder concept that can be built by the private sector on an economical basis, with the Federal Government playing a strong but limited role. In fact, during the past year, we have encouraged and supported industry to develop advanced reactor designs aimed at meeting sound economic, reliability, and safety criteria.

The Clinch River Project has produced valuable experience in the areas of design, component testing, and licensing. This information will be retained for use in the restructured base technology program. NRC's Atomic Safety and Licensing Board recently issued a memorandum of findings which resolved all issues in the CRBR Construction Permit hearings in favor of the Applicants. This decision, which would have been sufficient to authorize the issuance of a construction permit provides firm conclusions regarding the safety and environmental acceptability of breeder reactors and provides a benchmark for future breeder licensing efforts. Clinch River Project closeout activities are proceeding smoothly. An appropriation transfer of $40 million has been made from the Uranium Enrichment Program as an interim measure to fund CRBRP termination requirements. No new appropriations are expected to be requested in FY 1985.

The LFMBR research and development program in FY 1985 will be directed toward improving the technology for power conversion systems, components, instrumentation, and materials technology to the point where cost reduction and reliability potentials are realized. Continued operation of the breeder test facility complex at the Hanford Engineering Development Laboratory (HEDL) and the Energy Technology Engineering Center (ETEC) will provide the experience base and test capability for this effort.

The program will also assess advanced breeder concepts that offer the potential of improved economics and safety. These studies will include investigation of smaller scale breeders, standardized designs, and reactors manufactured as a complete package or as modules in central fabrication facilities. They will be conducted with input from industry, the ultimate customer for breeders. Moreover, cooperative research with, and technology transfer to, the private sector will constitute an important element of development activity.

Another priority element of our program will be a substantial increase in international cooperative effort. We see significant benefits to be gained from the division of workload and the pooling of resources. We also anticipate that joint effort will encourage uniform or compatible safety standards, physical security measures, and safeguards.

In FY 1985, we will continue development of the breeder fuel cycle technology as well as confirmation of fuel breeding in a light-water reactor using the uranium-233 fuel cycle. Our breeder fuel cycle program, however, will be conducted at a substantially lower level of effort. The lower funding recognizes the reduced requirements in both pace and extent for breeder fuel cycle technology development as a result of the Clinch River termination. It is my personal belief that this is a period of reassessment and that circumstances will evolve that will signal the need for more aggressive development of the breeder fuel cycle.

Advanced Nuclear Systems

Another important area of Department activity is the research and development of advanced nuclear systems in support of U.S. military and civilian space missions and other special applications. Work is divided into two major subprograms. The first is the Special Isotopic Power Sources Program. In FY 1985, flight systems development, production, and safety support will be conducted for isotopic power generators to be used in the Galileo and International Solar Polar spacecraft to be launched by NASA in 1986. Design efforts for an advanced modular generator to be used in space missions and for other special applications will be continued. A second program element is the Space Nuclear Reactor Program, which is a cooperative effort of the DOD, NASA, and DOE to examine several reactor concepts for potential use in future space missions.

Waste Technology

As you know, Mr. Chairman, under the requirements of the Nuclear Waste Policy Act of 1982, the activities associated with the siting, construction, and operation of a national repository system for high-level nuclear waste were assigned to the newly established Office of Civilian Radioactive Waste Management.

Prior to that, in 1980, legislation was enacted stating that the responsibility for disposal of low-level nuclear waste rests with the States. My role in nuclear waste management is to develop waste treatment technologies for the long-term management, storage, and disposal of civilian radioactive waste, be it low-level, high-level, or transuranic. In FY 1985, one of our activities will be to conduct safety and reliability tests on the ceramic melter system that is used to solidify high-level wastes. We will also continue to provide technical assistance to the States in their efforts to establish (either individually or by regional compacts) facilities for low-level waste disposal. In this regard, I am pleased to report that progress in forming compacts has been encouraging. To date, four compacts await Congressional approval and two more have been approved by the required number of States (four) in each region to permit submission to Congress.

Remedial Actions

Another important Federal responsibility in the management of nuclear wastes is our program for remedial actions at certain contaminated facilities and sites. This program is divided into four major subprograms: (1) The Formerly Utilized Site Remedial Action Program (FUSRAP) covers former nuclear processing sites that require stabilization or removal of contaminated material. DOE currently has authority for conducting remedial action at 19 sites. In FY 1985, remedial action will be completed at the Niagara Falls Storage Site in New York, and work will continue at other sites for which DOE has authority. (2) The Uranium Mill Tailings Remedial Action Program (UMTRAP) is directed toward the cleanup of 24 inactive uranium mill tailings disposal sites and several thousand associated vicinity properties. In FY 1985, cleanup will be completed at the site in Canonsburg, Pennsylvania, and about one-third of the necessary work at the Salt Lake City, Utah, site and about two-thirds at the Shiprock, New Mexico, site will be completed. (3) A third program covers our participation in a Federal/State cooperative effort to remove uranium mill tailings used for construction purposes in Grand Junction, Colorado. By the end of FY 1985, we will have completed remedial actions at 623 of the 626 structures requiring attention. (4) The Surplus Facilities Program provides for the safe management and disposition of contaminated DOE civilian program facilities (currently grouped into about 55 projects) that are no longer in use. In FY 1985, dismantlement of the Shippingport Atomic Power Station will be initiated, which will demonstrate the safe and economical cleanup of a commercial power reactor.

Yet another waste management activity for which we have responsibility is the demonstration of high-level waste solidification at the Western New York Nuclear Center, near

West Valley. In FY 1985, the West Valley Program will focus on vitrification testing, engineering, and procurement of waste solidification support systems and decontamination and decommissioning of the facility.

Uranium Enrichment

I have saved discussion of one of the Department's business enterprises -- the Uranium Enrichment Program -- for last. The FY 1985 enrichment request, which represents a 24 percent reduction from the FY 1984 appropriation, supports a program approach that is substantially changed from that of previous years. This major departure from "business as usual" operations has been necessitated by a series of events and circumstances that have threatened the ability of the United States to remain a viable long-term supplier of uranium enrichment services.

When I appeared before this Committee last year, I described the complex and interrelated problems that were frustrating the attempts of the Department to be a competitive supplier of enrichment services. Decreased demand and the worldwide excess of enriched uranium (the current inventory of enriched uranium is sufficient to meet the requirements of the next 3 years without additional production); increasing competition from foreign enrichment suppliers (Urenco and Eurodif); the emergence of a secondary market; and the major shift in foreign currency exchange rates have all taken a heavy toll on our enrichment enterprise. Underlying and aggravating these problems has been the failure of the U.S. Government to operate the enrichment enterprise in a businesslike manner.

In response to this untenable situation, the Department of Energy has developed and begun to implement a strategy designed to reverse the erosion of the U.S. enrichment market share. Today I am prepared to describe this strategy, which I believe will enable us to survive this transition period and to emerge in a commanding financial and technological position.

Basic to our effort is a fundamental change in management philosophy. The monopolistic mindset that has prevailed since the early days of the enterprise must yield to an attitude of healthy, aggressive competition. Enrichment operations can no longer be driven by an undisciplined, pie-in-the-sky production strategy. Rather, decisions must be responsive to the realities of the marketplace.

The overall objectives of the Department's revised enrichment strategy are as follows:

1. To be responsive to the needs of our customers.
2. To be a reliable long-term supplier at predictable prices.

3. To offer enrichment services at the lowest reasonable price, based on sound business practices.

4. To operate the enrichment complex without Federal subsidy.

In meeting these objectives, the Department is focusing on several interrelated elements that must be initiated in tandem. The first element -- and it is prerequisite to the others -- is to stabilize the U.S. enrichment market. Our primary vehicle for doing so is the issuance of a new Utility Services Contract. This contract, we believe, is both responsive to customer needs and cognizant of the DOE requirement for stable and predictable revenues. A second element of our strategy is to plan and conduct the activities in all areas of the enrichment enterprise more efficiently and more cost-effectively. And finally, when we are assured of our market position, we intend to initiate actions to encourage a greater degree of private sector participation in new investments.

After consultation with many knowledgable sources -- most particularly, our enrichment customers -- the Department issued the new Utility Services Contract on January 18th. The key features of the contract are:

- A reduced price ($135/SWU) for separative work, with a long-term price ceiling

- A customer option to offset up to approximately 30 percent of requirements by purchases either from the secondary market or from foreign suppliers
- Shorter leadtimes (180 days) to confirm delivery quantities
- Flexibility to select a variable tails assay option
- Flexibility to terminate contracts with no termination charges, provided 10 years advance notice is given to the Department.

Overall, the new contract offers significant advantages to our existing customers and to prospective new customers. Fixed Commitment Contract customers have the opportunity to convert to a contract with a substantially shorter fixed commitment period, to gain partial relief from their existing contractual future-year delivery commitments, and to work off their existing inventories. Requirements Contract customers will benefit from the lower price and from the ability to purchase a portion of their requirements from the U.S. and foreign secondary markets at even lower prices. In addition, Requirements Contract customers could use the variable tails assay option, which they currently cannot do.

Since the new contract is based on customer needs rather than on fixed commitments, we would not continue to feed the secondary market. To the contrary, the ability to purchase up to 30 percent of requirements from the market would work away excess SWUs, and it is conceivable that the secondary market could dry up as early as 1986. Future price adjustments would be based on known economic indicators, thereby ensuring predictability in the cost of enrichment services.

The reaction to the new contract by both foreign and domestic enrichment customers has been most encouraging. Representatives of the Edison Electric Institute, whose members include the vast majority of DOE's enrichment customers, testified before Congress last month concerning the Department's Utility Services Contract. They commented as follows:

> ". . . we are encouraging our members to give the US contract the serious consideration it is due . . . . The new contract appears to be beneficial to the domestic ratepayers, to the balance of trade for the Nation, to achieving an enrichment program that is responsive to the overall market needs, and to encourage the proper allocation of limited Federal resources."

On February 6, I signed the first Utility Services Contract with Duke Power, with a value of over $2 billion in future sales. Duke elected to purchase 100 percent of its requirements from DOE. In addition, Commonwealth Edison Company has given the Energy Department a letter of intent declaring that it will accept the new contract. The Chicago-based utility now holds 15 separate enrichment contracts with DOE -- 10 Requirements Contracts and 5 Adjustable Fixed Commitment Contracts -- all of which will be converted to the new Utility Services Contract. Commonwealth Edison represents about 6 percent of the total DOE enrichment service market, with annual purchases of about 1 million separative work units at a value of about $135 million annually. Currently, enrichment customers representing 54 percent of DOE's market have signed the new contract or letters of intent indicating their willingness to convert. We believe these actions indicate that the new contract has every likelihood of obtaining a high rate of conversion.

The new market-driven strategy remains based on the principle of full cost recovery. This means that the customer will continue to pay the full cost of operating the enrichment enterprise. The extent to which existing customers convert to the new contract, however, will have a profound effect on the development of our operating plans, our plant expansion program, and our research and development activities. In the past, a comprehensive strategy was developed in these three major areas, using sophisticated long-term cost minimization analytical techniques. After determining the strategy, a price was computed to recover all costs, and customers were charged accordingly. Today's competition will no longer permit such market-independent practices.

We are bound by contract to produce SWUs. The cost of that production must and will be recovered from our customers. Beyond production, activities such as research and development and capacity expansion are discretionary, and their extent and timing must be carefully considered. Under the new strategy, one of the major factors affecting these decisions will be "what we can afford." After we have recovered the full cost of production, funds will be available annually for research and development, construction of new capacity, or reduction of customer prices below $135/SWU. The actual amount of funding available will depend on the rate of conversion to the new contract.

Control of Program Costs and Customer Prices

The key to remaining competitive in the enrichment marketplace is to offer a contract with favorable price and flexible terms. Continuation of the previous production-driven strategy, with large outlays for Gaseous Diffusion Plant (GDP) operations, Gas Centrifuge Enrichment Plant (GCEP) construction, and the development of advanced technologies, would have produced a cumulative cash flow deficit of approximately $2 billion by 1990, severely impairing our ability to finance these activities. The earlier strategy was also raising serious concerns about our prediction of price stability or price reductions in the long term. The new market-driven strategy employs a vigorous cost reduction program with two major components.

The first component involves the operation of existing production capacity. The Department is making an earnest attempt to obtain relief from high power costs, to reduce outlays for GDP operations, and to operate the existing complex in the most cost-efficient manner possible. After the extent of conversions to the Utility Services Contract is determined, we will make an assessment as to how many GDPs should be operated, what their operational mode should be, future power purchases, reduction of program overhead, etc. These decisions cannot and should not be made until hard market data are in hand, but our strategy includes a firm commitment that we will pursue effective cost control in both the near and long term. This commitment is illustrated by the inclusion of a cost ceiling in the new contract.

The second cost control element relates to future investment decisions, including the level of research and development and the construction of new capacity. These decisions will also be market driven. In the near term, our strategy includes a continued commitment to develop and deploy new technologies for uranium enrichment. The funding level and pace of these programs, however, will be based on a more businesslike approach of adjusting outlays in proportion to revenues.

In the near term, we plan to continue research and development work on both the advanced gas centrifuge (Set V) and the Atomic Vapor Laser Isotope Separation (AVLIS) processes. A detailed evaluation is underway that will assess the technical feasibility and economic potential of both options. The Department's objective is to determine at the earliest possible date which of the two should be pursued through the demonstration and deployment stage. We believe that we will be in a position to make this decision in mid-FY 1985. Recently, we have begun the process of establishing detailed evaluation criteria with the help of the advanced gas centrifuge and AVLIS program participants. We also plan to place an independent third party under contract in the very near term to assist us in the evaluation. The technology option that is not selected may continue to be developed at a reduced pace, to assure that a fallback alternative exists.

Our FY 1985 budget reflects this approach, with research and development expenditures set at about 9 percent of expected revenues. In future years, total research and development expenditures will be based on development needs and available revenues.

With regard to new capacity, the Department intends to proceed in FY 1985 with construction of GCEP Process Buildings 1 and 2 and procurement of Set III centrifuges. Construction beyond Process Buildings 1 and 2 will be determined by responses to the new contract and results of the technology selection. We are now rescoping the GCEP project to minimize overall project costs, particularly the outlays for procurement of Set III machines. This course of action allows the pace for completion of GCEP to be driven by the marketplace. It also offers the potential for improved GCEP economics through greater use of the more efficient Set V machine (provided its development is successful) in the first two buildings.

As mentioned previously, another consideration in our strategy is to finance future capacity additions like GCEP by private sector contribution to the greatest degree possible. This will assure that those who benefit from the new technology will also bear its cost. Realistically, we believe that this element must await a more stable market position and the presence of a long-range planning base. The information to support long-range decisions will be available when the period for contract conversions closes, in September of this year. Accordingly, it is our objective to present specific recommendations for increased private sector participation to the Congress in concert with our FY 1986 budget request.

In summary, Mr. Chairman, the nuclear programs we are describing today differ markedly from those of the past. We have acknowledged the realities of the marketplace and have introduced modern principles of good business into our programs. In recognition of the constraints of the current national fiscal policy, we have set strict priorities for sharply focused activity. And we have a clearer delineation of government/industry responsibilities. One thing that has not changed, however, is our belief in a strong nuclear option and our commitment to strive for its realization. We look forward to working with this and other committees of Congress in achieving this objective.

I would now like to describe in greater detail the Department's nuclear programs.

Converter Reactor Systems

The FY 1985 budget request for Converter Reactor Systems is $83.5 million, a decrease of $9.2 million from the FY 1984 appropriation. The distribution of funds is as follows:

Program Element	FY 1984	FY 1985
	($ in Millions)	
Light-Water Reactor Systems	$ 19.5	$ 16.0
High-Temperature Reactors	30.0	34.6
Advanced Reactor Systems	5.0	0.0
Three Mile Island Activities	37.0	32.2
Program Direction	1.2	0.7
Total	$ 92.7	$ 83.5

Note: The FY 1984 numbers reflect comparabilities.

The overall goals of the Converter Reactor Systems Program are: (1) to improve the economic and safe use of nuclear reactors; (2) to contribute to the resolution of the nuclear industry's regulatory, financial, and institutional problems; and (3) to fulfill the Federal Government's research and development commitment associated with General Public Utilities' cleanup of Three Mile Island (TMI).

Light-Water Reactor Systems

The Advanced Reactor Evaluations element of our program will focus on safety in improved advanced converter reactors. While the current LWR industry has an outstanding safety record, improvements can be made to any technology. The basic question of how changes in the current size and design of commercial converter reactors could improve safety (both real and perceived) and better meet utility needs will be addressed by this program.

The Department will continue to fulfill its role of reviewing and reporting to Congress on the national research and development programs conducted by private sector and government organizations, as required under P.L. 96-567.

We will also continue participation in the Loss-of-Fluid Test (LOFT) Program, an internationally funded activity under the auspices of the Nuclear Energy Agency (NEA) of the Organization for Economic Cooperation and Development (OECD). This consortium selected a test program to be carried out over a 3-year period beginning in FY 1983. During that year, three thermal-hydraulic tests were successfully performed within budget and ahead of schedule. In FY 1984, the final three thermal-hydraulic tests will be completed, and preparations will be made for two fission-product release and transport tests. These fission product tests, to be performed in FY 1985, will provide important data relevant to the magnitude of the radioactive source term, which is a significant input to the technical basis underlying many nuclear licensing and regulatory requirements. By early FY 1987, all analysis should be completed and the LOFT reactor deactivated and decontaminated.

The original cost estimate for the LOFT Program was $93.5 million. Of this, NRC provided $25 million in FY 1983, DOE is providing $45 million in increments of $15 million in FY 1984, 1985, and 1986, the Electric Power Research Institute is contributing $1.5 million, and foreign countries are expected to contribute $22 million.

High-Temperature Reactors

Following completion in FY 1984 of activities related to the design of a proposed large high-temperature gas-cooled reactor (HTGR), efforts in FY 1985 will be refocused to evaluate the potential of small HTGRs for unique domestic and international markets. In addition, the development of the technology base needed for HTGR electric and process heat applications will be supported. These activities and objectives are consistent with the current policy of support for long-leadtime, high-technology advanced concepts that cannot be fully supported by the private sector.

The primary thrust of this program will be to evaluate and develop the potential of small gas-cooled reactors for multiple applications. Technical and economic design assessments will be performed to guide the base technology development activities and the selection of a reference small reactor concept. The technical approach is to utilize the inherent lower power density of small HTGRs to minimize the need for engineered safety features. The evaluation and development of the HTGR concept will be closely coordinated with appropriate user groups to assure evolving marketplace compatibility. Alternative market, business, and financial strategies will be developed by the users, consistent with their needs and requirements, in order to guide the evaluation of the small HTGR and the configuration of the HTGR which best meets the needs of the market.

The HTGR program will also emphasize the advancement of the technology base needed to support the development of small, gas-cooled reactor systems with less complex safety systems. Additionally, technology activities will be performed to address many of the technical design safety issues that have been identified from the operational experience gained at Fort St. Vrain, from changes in nuclear regulation, and from changes in user (utility) requirements.

Advanced Reactor Systems

In FY 1984, efforts have continued on irradiation testing of candidate replacement low enriched uranium (LEU) fuel systems and fabrication development to qualify commercial sources of these alternative fuels. In FY 1985, funding for this program is not being requested by the Department of Energy; however, the Arms Control and Disarmament Agency has requested funding to support this activity in FY 1985.

Three Mile Island Activities

The Three Mile Island (TMI) Program is budgeted under the Converter Reactor Program but is managed under the Office of Terminal Waste Disposal and Remedial Action, and is discussed under that section of this statement.

Breeder Reactor Systems

The Breeder Reactor Systems budget request for FY 1985 is $308.1 million, a decrease of $115.1 million from the FY 1984 appropriation. Distribution of the funds is as follows:

Program Element	FY 1984	FY 1985
	($ in Millions)	
Clinch River Project Termination	$ 40.0[a]	$ 0
Liquid Metal Fast Breeder Reactor	300.8	261.6
Nuclear Fuel Cycle	35.4	11.9
Water-Cooled Breeder	35.5	26.3
Program Direction	11.5	8.3
Total	$ 423.2	$ 308.1

[a] An Appropriation Transfer of $40.0 million has been made from Uranium Enrichment as an emergency interim measure to fund immediate CRBRP termination requirements.

Note: The FY 1984 numbers reflect comparabilities.

Liquid Metal Fast Breeder Reactor Program

The Liquid Metal Fast Breeder Reactor (LMFBR) Program has been restructured to focus on resolving those technology issues that are key to improved breeder economics and predictable, safe performance. The revised program will be fully consistent with our National energy research and development policy, in that there will be no new Federally funded demonstration projects. The responsibility for commercialization of breeder reactor technology, including definition of program scope, timing, funding arrangements, and management, resides with the private sector. The Federal program for FY 1985 complements industry efforts by emphasizing:

- Technology research and development necessary for a breeder system that has less complicated safety systems, is reliable, is competitive with alternatives, and meets the market needs of utilities
- Development of advanced plant concepts,
- Major, substantial international collaboration, and
- Development of LMFBR fuel cycle technology.

A major effort will be directed toward advancing the technology for power conversion systems, components, instrumentation, and materials technology, as well as for the related fuel supply system, to the point where cost reduction and reliability potentials are realized. Testing of breeder systems, fuels, components, instruments, and materials takes place at the Hanford Engineering Development Laboratory (HEDL), the Energy

Technology Engineering Center (ETEC), and the Argonne National Laboratory (ANL).

Recent studies indicate that advanced breeder concepts can be economically competitive with alternatives (e.g., LWRs and coal plants) and deployed with relatively short leadtimes in sizes matched to various grid requirements. The feasibility of these advanced breeder concepts will be assessed with input from the user industry, the ultimate customer for breeders. Explicit attention will be given to the potential advantages of smaller reactors of standard design that are capable of being replicated in total (or by module) in central fabrication facilities. Smaller sized fuel cycle facilities also have attractive economies to match plant sizes. Cooperative research with, and technology transfer to, the private sector will constitute an important element of the reoriented breeder program.

A major thrust of the FY 1985 program will be the emphasis on international collaboration in breeder technology to reduce U.S. program costs and to retain the U.S. role in international nuclear forums. The experience gained in design, component testing, licensing, and analysis from the CRBRP Project, as well as our advanced breeder knowledge acquired from the operation of the Fast Flux Test Facility (FFTF) and the base program, will be valuable in establishing exchange agreements with other nations.

A smaller scale effort, the Water-Cooled Breeder Program, is devoted to proving that breeding can be achieved in a light-water reactor using the uranium-233/thorium fuel system. Efforts in FY 1985 will continue the defueling activities and core evaluation of the light-water breeder core from the Shippingport Atomic Power Station.

Clinch River Breeder Reactor Project

There were no funds appropriated to continue the Clinch River Project in FY 1984. Therefore, on November 10, 1983, the parties involved -- the Department of Energy (DOE), Tennessee Valley Authority (TVA), Commonwealth Edison, Project Managment Corporation (PMC), and the Breeder Reactor Corporation (BRC) -- agreed to terminate the project, effective November 14, 1983. The agreement was formalized on December 19, 1983.

Termination activities began in early FY 1984 and are planned for completion in early FY 1985. These include the termination and/or relocation of project personnel; termination of contracts and subcontracts; site redress work; settlement of terminated contracts and subcontracts; documentation of certain completed work; completion of selected computer verification efforts that were approaching completion when the project was terminated; arrangement for retention and appropriate availability of scientific and technical information generated under the project;

storage, maintenance, relocation of CRBRP components, equipment, materials, etc., for use within the LMFBR Program and other Government programs, as appropriate; and disposition of inventories not of value to the LMFBR Program.

Large-Scale Prototype Breeder

The Government-sponsored design efforts on a Large-Scale Prototype Breeder (LSPB) plant will be phased out in an orderly manner during FY 1984. The program has been a joint effort of the U.S. Government and private industry to develop a large-scale prototypical breeder demonstration plant. The plant was to have been the logical follow-on to the Clinch River Project as a full-scale demonstration plant. The LSPB design will be maintained as a frame of reference for benchmarking advanced concepts developed under the base program.

LMFBR Base Program

The mission of the LMFBR Base Program is to develop the requisite technology to the point where the private sector is able to construct and operate safe, reliable liquid metal fast breeder reactor plants for supplying electricity to the grid. This includes studies of the technical features applicable to future private sector initiatives. The program has been reoriented to place primary emphasis on designing less complicated safety systems and achieving economic competitiveness in future advanced concepts. It is to this end that the breeder technology and test facilities efforts discussed in the following paragraphs are directed.

Concepts and Requirements Development. An effort will be initiated to identify plant concepts that could be developed by industry for use in the marketplace and to assess unique market needs that can be satisfied by the breeder technology program.

During FY 1985, development efforts on the advanced concept studies will be conducted by contractors selected during FY 1984 as part of a competitive procurement process. This effort will include development of plant requirements and safety criteria; safety analyses; licensing assessments; seismic evaluation; constructability assessment; identification of research and development requirements; and analysis of cost and schedule potential. Market analysis will be conducted to assure proper program and concept development. The studies will utilize to the maximum extent possible previously developed technology and information gained under current international collaborations, including the DOE-Japanese MONJU agreement. Research and development requirements will be constantly coordinated with other parts of the base program.

Beginning in FY 1984 and during FY 1985, an information exchange will be conducted with the Nuclear Regulatory Commission (NRC), aimed at developing licensing criteria for future advanced LMFBRs. Key LMFBR issues will be identified and used as a basis for improving the licensability of LMFBRs and contributing to an efficient licensing process.

Power Conversion Technology. It is essential that major cost reduction and reliability potentials are realized in order to justify investor and public acceptance to build and operate economically competitive LMFBRs. The Power Conversion Technology Program focuses on these potentials and encompasses the power conversion systems and the components necessary to convert heat to electricity. Standardized plants and more cost-effective methods for achieving quality assurance are two concepts of special interest for accomplishing the reduced cost and increased reliability goals.

The research and development to improve the performance predictability and reliability of power conversion components include flow-induced vibration analysis, flow distribution testing and analysis, mixing and stratification testing and analysis, subcomponent development and testing, fabrication process development, inspection development, and procedure development. Efforts are underway to develop data on materials properties, including fabrication and environmental effects. Documentation of these data in handbook form will serve as an authoritative source for use in the design and licensing processes. The program also includes the development of a new ferritic alloy that offers significant economic and engineering advantages over current reference structural alloys.

Significant accomplishments for FY 1984 include: successful completion of sodium testing of the 35,000 gpm pump, which disclosed the need for modifications that would not otherwise have been discovered; successful completion of sodium testing of the hockey stick steam generator in both the recirculation and once-through modes; and successful completion of water testing of the 85,000 gpm two-stage prime pump, preparatory to shipping all pump system parts to ETEC by the end of 1984.

Specific accomplishments planned for FY 1985 include: to continue preparations for sodium testing of the helical coil model steam generator; to develop a 14,000 gpm electromagnetic primary sodium pump for modular reactor applications; and to initiate balance-of-plant cost reduction, simplification, and standardization studies. Fabrication of the 70 MWt double-wall tube steam generator will continue, with delivery in FY 1986. Development of this component has the long-term potential for eliminating the intermediate sodium system and avoiding the need for a sodium-water reaction product separation system.

Fuel Performance and Supply. The objectives of the Fuel Performance and Supply Program include proving the performance of fuel, blanket, and absorber core components under prototypic operating conditions and demonstrating safe, reliable, and licensable core systems. Specific objectives include extending the lifetime of core components to a minimum of 3 years; automating fuel fabrication to achieve competitive fabrication costs; improving safeguards and reducing personnel exposure; and transferring developed technology to industry.

The development of carbide and metal fuels for advanced and smaller sized plants will proceed because of the potential advantages in smaller control requirements, smaller sizes, and lower fuel cycle costs that these fuel systems offer. International participation in the Core Systems and Materials Program will continue to reduce program costs while maximizing technological benefits.

In the fuel supply area, activities will continue toward completing the Secure Automated Fabrication (SAF) line. Procurement of equipment and its installation in the Fuels and Materials Engineering Facility (FMEF) will continue. Upon its completion and operation in the late 1980's, the SAF line will demonstrate breeder fuel fabrication technology that can be deployed commercially by industry. Activities for fuel assembly capability in the FMEF will be initiated in FY 1985.

Nuclear Systems Technology. The disciplines of safety, physics, structures, thermal hydraulics, and reactor core design are integrated into a single, cohesive unit in the Nuclear Systems Technology Program. The program will focus on experimental verification, in existing DOE facilities, of the feasibility of advanced reactor concepts of varied design, size, and fuel type that exhibit self-terminating capability under failure conditions. All functions needed to assure nuclear safety under abnormal conditions are integrated into the nuclear systems. Demonstration of inherently safe operation of nuclear systems will reduce the requirements for supporting auxiliary equipment whose purpose is to control otherwise dangerous conditions. Such support equipment substantially increases the complexity of reactor designs. These studies will enable the development of a reliable advanced technology that is competitive and compatible with user needs and capabilities.

Varied fuel types (metal, oxide, carbide) and fuel pin sizes will be evaluated, as well as the effects of varied core designs on voiding, temperature, and reactivity coefficients. Features supporting inherently safe operation will be developed, reflecting the redirection in the safety program, which places more emphasis on the existing safety features of breeders and less on breeding ratios and other plant parameters.

Work will continue in support of upgrading the TREAT reactor to provide the principal in-reactor safety phenomena testing capability. Also, a program of operational safety experiments on integrated systems will be conducted at the EBR-II reactor facility.

Test Facilities. The test facilities effort consists of operating and maintaining facilities at the Hanford Engineering Development Laboratory (HEDL), the Energy Technology Engineering Center (ETEC), and the Argonne National Laboratory (ANL) to meet LMFBR program test requirements. In addition, the Los Alamos National Laboratory (LANL) conducts nuclear-related studies and assessments in support of the program.

HEDL Facilities

The Hanford Engineering Development Laboratory (HEDL), which is operated by Westinghouse Hanford Company in Richland, Washington, plays a key role in breeder reactor development and testing activities. The major test facility at HEDL is the Fast Flux Test Facility (FFTF), which provides a test bed for demonstrating and evaluating the performance of breeder reactor fuel assemblies and partial core loadings at reference conditions. Efforts will focus on operation of the FFTF and the installation of the Secure Automated Fabrication line equipment.

Facilities operated at the HEDL site include:

- The FFTF, which is a 400 MWt liquid metal (sodium) cooled fast neutron flux loop-type reactor designed specifically for irradiation testing of nuclear reactor fuels and materials for fast breeder reactors.

  The performance of the FFTF during 1983 and 1984 is particularly noteworthy: three full cycles of operation were completed. The reactor was operated for a nominal 100 days during each cycle and, in the third cycle, experienced 55 days of continuous full-power operation without interruption. The performance of the fuel subsystem exceeded its design goal burnup of 85,000 megawatt-days per tonne during the third cycle, without failures.

- The Fuel Storage Facility, located adjacent to the FFTF, is used to store and remove decay heat from irradiated FFTF fuel and reactor experiments.

ETEC

The Energy Technology Engineering Center (ETEC), which is located 40 miles northwest of Los Angeles and is operated by Rockwell International, is the breeder program's non-nuclear component testing center. ETEC has several large on-site non-nuclear sodium testing facilities with the unique capability to test fast breeder reactor components under all operating conditions. Some smaller ETEC facilities will be used for testing of selected small reactor plant components, instrumentation, and subsystems. Efforts will continue toward realizing innovative methods for economical long-term steam generator testing.

ANL Facilities

The Argonne National Laboratory (ANL) efforts are primarily accomplished at the ANL West (ANL-W) site at the Idaho National Engineering Laboratory. These activities include plant and component operating experience in addition to specific testing efforts in support of fuel performance and nuclear systems technology.

Development of innovative methods to achieve economical long-term testing of key components such as pumps, steam generators, and inherent safety features is a continuous effort in parallel with testing activities.

Facilities that are operated at the ANL-W site include:

- The Experimental Breeder Reactor II (EBR-II)
- The Hot Fuel Examination Facility (HFEF)
- The Zero Power Plutonium Reactor (ZPPR)
- The TREAT (Transient Test) Reactor.

Los Alamos National Laboratory (LANL)

The LANL efforts are primarily general program and nuclear studies and assessments and nuclear training activities. Initiatives in support of cost-effective operations are being implemented throughout the test facilities complex. Cost and schedule controls ensure efficient use of the test facilities; consolidation of testing and demonstration activities is continuously under review. Facilities surplus to base program needs will be phased out.

Nuclear Fuel Cycle

The fuel cycle activities include development of advanced technology for reprocessing of irradiated fuels from nuclear power reactors, with emphasis on the more stringent requirements associated with reprocessing of breeder reactor fuel. These include higher thermal and radiation burdens, higher fissile content, sodium contamination, and more complex fuel assembly structures. The technical program is focused on development of technology that will provide smaller-scale facilities for equivalent throughput, reduced radiation exposure to workers, increased environmental protection, increased reliability, enhanced safeguards, and reduced costs.

In FY 1984, design, fabrication, and testing of advanced, smaller size, higher throughput equipment in the Integrated

Equipment Test (IET) facility at Oak Ridge will continue to evaluate performance and remote maintenance concepts. Specific items to be tested include fuel disassembly and shear systems, a continuous rotary dissolver, centrifugal contactors for solvent extraction, and an advanced servomanipulator needed for remote operations and maintenance.

In FY 1985, remotely operable and maintainable reprocessing equipment and systems will be developed, and some integrated cold testing in the IET facility will be conducted. Laboratory and hot cell experiments on flowsheet development will continue at a reduced level. Efforts in FY 1985 will also include providing supporting analysis and evaluation for the light-water breeder reactor proof-of-breeding demonstration and evaluating methods and cask designs for the handling and shipping of irradiated breeder fuel.

Water-Cooled Breeder

The mission of the Water-Cooled Breeder Program is to develop technology for significantly improving the efficiency of nuclear fuel resource utilization by light-water reactors used for electrical power generation. The objective is to accomplish the following: to prove that breeding can be achieved in a light-water nuclear reactor using the uranium-233/thorium fuel system; to confirm a practical way to use thorium (a plentiful source of fuel for which there has been no major energy-related use); to show the feasibility of installing pre-breeder and breeder cores of the light-water breeder reactor type in existing and future pressurized-water reactor plants, using current types of plant components and systems; and to make the technology developed under the program available to industry.

A light-water breeder core was installed in the Shippingport Atomic Power Station in 1977. On October 1, 1982, the Shippingport Station ceased power operations. End-of-life testing was performed, and defueling of the light-water breeder reactor core was begun.

Core removal operations are scheduled to be completed by the end of FY 1984. Major activities in FY 1985 will include: completing documentation of core removal operations; preparing for long-term storage of expended fuel; and shipping of spare and physics fuel rods to storage.

Core evaluation work in FY 1985 will include: disassembling light-water breeder core fuel modules for examination and storage; providing facilities and equipment for light-water breeder fuel module examination and assay; preparing fuel rods for nondestructive assay; performing proof-of-breeding work; analyzing effects of extended core operation on core materials; and continuing thermal and hydraulic analysis of light-water breeder reactor components.

Advanced Nuclear Systems

The Advanced Nuclear Systems budget request for FY 1985 is $33.5 million, a decrease of $0.6 million from the FY 1984 appropriation. Distribution of the funds is as follows:

Program Element	FY 1984 ($ in Millions)	FY 1985
Special Isotopic Power Sources	$ 27.7	$ 28.0
Advanced Systems Evaluation (Space Nuclear Reactor)	5.0	4.5
Program Direction	1.4	1.0
Total	$ 34.1	$ 33.5

Note: The FY 1984 numbers reflect comparabilities.

The goal of the Advanced Nuclear Systems Program is to develop and deliver specialized nuclear power sources for U.S. military and civilian space missions and other special applications. Activity is conducted within two program elements: the Special Isotopic Power Sources Program and the Space Nuclear Reactor Program. The latter is a tri-agency cooperative endeavor of DOD, NASA, and DOE.

The Advanced Nuclear Systems Program supports civilian and military space applications through the development of a range of nuclear power system options. A number of developed nuclear isotopic power sources are used by the Department of Defense and the National Aeronautics and Space Administration;

operating data from these systems are being reviewed. For example, Pioneer 10 (launched in 1972) and Pioneer 11 (launched in 1973) continue to transmit telemetry data which indicate that the space isotopic power supplies are operating as designed. In addition, the DOD Lincoln Experimental Satellites 8 and 9 (in orbit since 1976) and the NASA Voyager 1 and 2 spacecraft (launched in 1977) continue to obtain their total spacecraft power needs from their onboard isotope generators.

The current generation of Radioisotopic Thermoelectric Generators (RTGs) under development will deploy the General Purpose Heat Source (GPHS) for the NASA Galileo and International Solar Polar Missions, planned to be shuttle-launched in 1986. Each GPHS RTG weighs 123 pounds and produces about 285 We.

Special Isotopic Power Sources

The FY 1985 isotope power development program has three major activities. First is the readiness and shipment of the GPHS flight units to be used in the silicon-germanium generator for the NASA Galileo and International Solar Polar Missions. The second effort is the development of a new modular RTG concept that offers the potential for a more advanced, much lighter generator, i.e., high specific power to weight ratio, for future space missions. During FY 1985, ground demonstration system (GDS) fabrication and assembly will be accomplished.

The third activity involves RTG development for special military applications. In FY 1985, emphasis will be placed on the GDS fabrication, completion of final design definition, and the safety evaluation of the RTG.

Advanced Systems Evaluation (Space Nuclear Reactor)

The Space Reactor Development Program and the Space Power Advanced Reactor Program were consolidated to form the Space Nuclear Reactor (SP-100) Program, to support a Memorandum of Agreement signed on February 11, 1983, by the DOD's Defense Advanced Research Projects Agency, NASA's Office of Aeronautics and Space Technology, and DOE's Office of Nuclear Energy. The agreement establishes the relative responsibilities of the three agencies during the conceptual development phase of the program. In FY 1984, several reactor system concepts are being examined to determine which concept would enhance or enable future civilian and military space missions. Long lead efforts in technology development and related tasks began in 1983 and will continue through 1985. A key decision is planned during FY 1985 on whether to proceed with a ground engineering prototype demonstration. If a decision is made to proceed to a prototype, substantial increases in funding will be necessary in FY 1986 and beyond for the ground engineering test, for associated facilities improvements at a DOE laboratory or contractor location, and for the transition of the program into more detailed design and development activities.

The current multi-agency agreement expires at about the end of FY 1985. A new agreement will be necessary if a decision is made to proceed to the SP-100 Ground Engineering Test Phase (FY 1986-1989). Upon selection of a specific system for the final development, the management structure will be changed to a more traditional line structure with separate activities and clearly defined interfaces for each agency. DOE will be responsible for developing the nuclear subsystem during this phase.

During FY 1985, several reactor development system contractors will be funded in order to develop reactor conceptual designs for space system applications. Conceptual designs will be developed, and a baseline, backup, and growth design will be completed. System and nuclear safety program activities are to be continued in preparation for potential ground engineering systems tests scheduled for FY 1986.

Remedial Action Program

The FY 1985 budget request for the Remedial Action Program is $152.0 million, an increase of $53.0 million over the FY 1984 appropriation. The distribution of funds among the program elements is as follows:

Program Element	FY 1984	FY 1985
	($ in Millions)	
Formerly Utilized Sites	$ 17.0	$ 16.0
Grand Junction	1.5	1.5
Uranium Mill Tailings	27.9	54.0
Surplus Facilities	15.5	30.0
West Valley	36.0	49.4
Program Direction	1.1	1.1
Total	$ 99.0	$ 152.0

Note: The FY 1984 numbers reflect comparabilities.

The overall objective of the Remedial Action Program is to treat or stabilize radioactive wastes and perform required decontamination and decommissioning at contaminated DOE and legislatively authorized nongovernment facilities and sites. The major activities are: (1) the Formerly Utilized Sites Remedial Action Program (FUSRAP); (2) remedial action at Grand Junction, Colorado (P.L. 92-314, as amended); (3) the Uranium Mill Tailings Remedial Action Program (UMTRAP) for inactive uranium mill tailings sites (P.L. 95-604); (4) management of certain radioactively contaminated Department facilities declared surplus and resulting principally from civilian nuclear energy programs; and (5) demonstration of the solidification of high-level radioactive wastes at West Valley for final disposal (P.L. 96-368).

Formerly Utilized Sites Remedial Action Program (FUSRAP)

FUSRAP provides for remedial actions at former nuclear processing facilities, most privately owned, which became radioactively contaminated from Manhattan Engineer District or Atomic Energy Commission activities and which have not been decontaminated sufficiently to meet current health effects guidelines. To remedy the situation, the contamination will be either stabilized in place, with restrictions placed on use of the site, or removed and disposed of at another location. Authority derived from the Atomic Energy Act of 1954, as amended, currently exists for conducting remedial actions at 15 sites. This authority is based on our review of the involvement of agency predecessors in activities at these sites. Review of other sites involved in past activities of the agency's predecessors is continuing and may result in the addition of sites to the program. Congress added four new sites and $5.0 million in the FY 1984 Energy and Water Development Appropriations Act with direction to initiate, as a priority action, a decontamination research and development project at these sites and vicinity properties, bringing the program site total to 19. The Department's Oak Ridge Operations Office has the lead for implementing the program.

In FY 1984, we expect to complete much of the cleanup work for contaminated properties near the DOE-owned Niagara Falls Storage Site at Lewiston, New York. Other remedial actions on this site will be described in my testimony on the Surplus Facilities Program. We are also planning to complete remedial action at the Middlesex Landfill, New Jersey, and at the University of Chicago, Illinois. Material contaminated with uranium will be excavated from the Middlesex Landfill and stored temporarily at the nearby DOE-owned Middlesex Sampling Plant. At the University of Chicago, about 600 cubic feet of contamination in several laboratories will be removed and sent to the DOE disposal site at Hanford, Washington.

Preparations are underway to begin decontamination actions at Maywood, New Jersey; Wayne/Pequannock, New Jersey; Colonie, New York; and Hazelwood, Missouri -- sites which were added to the program in FY 1984. Cleanup of residential properties at Maywood and Wayne/Pequannock is scheduled to begin in March 1984, at Colonie in May 1984, and at Hazelwood in July 1984. Our general approach to these projects is to give priority to cleanup of contaminated vicinity properties and to store the waste temporarily on each processing site. We also will take steps to prevent any further offsite contamination from these four sites. For the longer term, the Congressional direction is to decontaminate the sites. Because of the large volumes of waste involved, we have asked each of the three States in which the waste is located to designate a site for disposal within the State. DOE would then proceed to acquire the site and effect disposal. These actions are expected to require more than 10 years to complete, at total costs exceeding $100 million. Due to the large quantities of material and the large costs associated with relocation, we will examine from the technical, environmental, and economic viewpoints the alternative of stabilizing the wastes at their present locations for two of the sites (Maywood and Colonie) and report the results to Congress.

Other survey, preliminary engineering, and environmental review activities are underway for the Albany Research Center at Albany, Oregon; the DuPont plant at Deepwater, New Jersey; and the Middlesex Sampling Plant at Middlesex, New Jersey. We are also continuing to monitor the Palos Park site in Illinois and the St. Louis Airport Storage Site in Missouri.

In FY 1985, the cleanup of contaminated properties near the Niagara Falls Storage Site at Lewiston, New York, will be completed. We will continue the priority decontamination projects at Maywood, Wayne/Pequannock, Colonie, and Hazelwood. Cleanup of the residential properties in Maywood, the adjacent properties in Rochelle Park and Colonie, and Latty Avenue in Hazelwood will be completed, and work will start on other vicinity properties. Design engineering and environmental analysis will be completed for the Albany, Oregon, site.

Grand Junction Remedial Action Program

Under Title II of Public Law 92-314, Congress authorized financial assistance to the State of Colorado to limit radiation exposure resulting from the use of uranium mill tailings for construction purposes in Grand Junction, Colorado. This State/Federal cooperative effort with the State of Colorado is administered by the Colorado Department of Health through the Grand Junction Area Office. The remedial action provides for removal of uranium mill tailings from the premises of about 626 structures where radon daughter exposures exceed the Surgeon General's guidelines. Public Law 95-236 extended the time for property owners to apply for inclusion in the program, which has now expired, and increased the authorized program funding. Federal funds cover 75 percent of the program costs, with the State providing the balance. FY 1986 is expected to be the last year in which Federal funds will be requested for the program.

Through FY 1983, work had been undertaken on 543 structures. In FY 1984, the program will continue with radiological assessments and will initiate remedial actions at about 50 structures. In FY 1985, the program will initiate and complete remedial action on 30 additional structures, for a total of 623 structures out of the 626 to be completed.

Uranium Mill Tailings Remedial Action Program (UMTRAP)

UMTRAP is responsible for conducting remedial actions at 24 former processing sites and several thousand contaminated vicinity properties as mandated by Public Law 95-604, "The Uranium Mill Tailings Radiation Control Act of 1978." Nine of the sites are designated as high priority, six as medium priority, and nine as low priority. The Act requires completion of the program within 7 years of the March 1983 promulgation of standards by the Environmental Protection Agency. Based on the results of an evaluation to assess the feasibility and budget impact of the mandated 7-year schedule, the Department has concluded that this schedule can be maintained. Project implementation is proceeding under baseline cost and schedule estimates that are consistent with the March 1990 completion date.

The current strategy is to focus near-term program activities on the higher priority sites and vicinity properties. Remedial actions are being conducted in accordance with cooperative agreements negotiated with the affected States and Indian Tribes. Federal funds cover 90 percent of the remedial action costs (100 percent for those sites on Indian lands). The type of remedial action for the processing sites will be either to stabilize the mill tailings in place, where feasible, or to remove the tailings to a new Federally owned disposal site.

Engineering plans and environmental documents will be prepared for the cleanup and disposal operations at each site. The concurrences of the NRC and the affected State or Tribe are required for each site remedial action plan. The program also includes the cleanup of contaminated vicinity properties. It is estimated that 5,000 to 6,000 vicinity properties, mainly in the Grand Junction area but not covered by the Grand Junction Program, may be found eligible for cleanup. The Albuquerque Operations Office has the lead role in implementing this program.

Specific accomplishments planned for the balance of FY 1984 include the continuation of remedial action at Canonsburg, Pennsylvania, and initiation of remedial action at Salt Lake City, Utah. The Salt Lake City schedule has been adjusted to reflect the plans to relocate the tailings to a site near Clive, Utah. Cleanup also will continue at high priority vicinity properties near the Canonsburg, Salt Lake City, and Grand Junction sites and will be started at Edgemont, South Dakota, and Durango, Colorado. Remedial action plans will be completed, with State or Tribe and NRC concurrences, for Shiprock, New Mexico, and Gunnison, Colorado, and will be initiated for Durango, Colorado; Riverton, Wyoming; Lakeview, Oregon; Tuba City, Arizona; and Mexican Hat, Utah.

During FY 1985, the work on the Canonsburg processing site and on the remainder of the 125 vicinity properties will be completed. The work at Salt Lake City will be brought to 30 percent completion, and remedial action will be started at Shiprock and Durango. Approximately 215 vicinity properties, located at several high priority sites, will be cleaned up.

Surplus Facilities Program

This program provides for the safe management and disposition of the inventory of surplus radioactively contaminated DOE-owned facilities from civilian nuclear energy development programs. The decontaminated facilities and sites are returned to other productive use where appropriate. All defense-related facilities are included in the Defense Nuclear Waste Management budget. The facilities are grouped into about 55 projects under this activity. In addition, the program develops improved methods for decontamination and decommissioning which can be transferred to industry. A long-range plan will be completed by the end of FY 1984 to establish the overall schedule and priorities for sites currently in the surplus inventory. Priorities are established and work schedules are developed through the analysis of legal, economic, and health and safety factors for each site. The Richland Operations Office has the lead field office role in implementing the program.

In FY 1984, the major onsite cleanup and upgrading of storage facilities will be completed at the Niagara Falls Storage Site near Lewiston, New York. Work to recondition contaminated facilities will continue at the Mound Laboratory in Miamisburg, Ohio. This 10-year project, which is equally funded by this program and by the Assistant Secretary for Defense Programs, began in 1978 and will be 61 percent complete by the end of FY 1984. Responsibility for the Shippingport plant will be taken over from Naval Reactors after all of the fuel has been shipped to the Idaho National Engineering Laboratory. Project offices will be established on the site by DOE and by the General Electric Company, which was selected in 1983 as the decommissioning operations contractor. Other activities in FY 1984 will include completion of an action plan for work to be done at Monticello, Utah. A geohydrologic study and an engineering analysis of alternatives for long-term management of the Weldon Spring site in Missouri will be completed, and a draft environmental impact statement (EIS) will be initiated. Decommissioning of several contaminated buildings at Argonne National Laboratory will also be completed.

In FY 1985, the decontamination and dismantling of plant systems at the Shippingport Atomic Power Station will be initiated. The United States has proposed to the Nuclear Energy Agency that this be conducted as a limited cooperative project; details of the cooperation are under discussion. DOE will assure transfer of this technology to U.S. industry by providing opportunities for participation and by making the experience from the project widely available.

At the Niagara Falls Storage Site, the capping of the stored residues will be completed, the final EIS will be completed, and a DOE decision on the long-term management of these contaminated materials will be made. The decontamination and renovation of facilities will be continued at the Mound Laboratory, and the project will reach 72 percent completion. Other activities in FY 1985 will include: removal of contaminated material and systems at Santa Susana, California; completion of the environmental review process for the uranium mill tailings site at Monticello, Utah; issuance of a draft EIS for long-term management of the uranium and thorium wastes stored at Weldon Spring, Missouri; removal of the TRIGA reactor vessel at the Center for Energy and Environmental Research in Mayaguez, Puerto Rico; and the decommissioning of Building 38 at Argonne National Laboratory.

West Valley Demonstration Project

The objective of the West Valley Demonstration Project is to demonstrate the solidification process for disposal of high-level nuclear wastes under the provisions of Public Law 96-368, the West Valley Demonstration Project Act of 1980. An integrated production-scale development and demonstration project for treating the high-level liquid nuclear wastes at the Western New York Nuclear Service Center, near West Valley, will be carried out.

Major activities to be performed as part of the project include: (1) decontamination required to prepare existing facilities and equipment to accommodate the solidification project; (2) removal of the wastes from the underground storage tanks; (3) development, design, construction, and operation of systems and necessary supporting facilities for the solidification of the wastes; (4) acquisition of containers for the permanent disposal of the solidified waste; (5) temporary storage and transportation of the solidified waste to an appropriate Federal repository for permanent disposal; (6) decontamination and decommissioning of the waste tanks, facilities, hardware, and material used in carrying out the project; and (7) disposal of low-level and transuranic wastes produced from the project activities.

The total cost of the project is now estimated to be $381.5 million (unescalated) through waste solidification (exclusive of final decontamination and decommissioning of the facility).

In FY 1984, the major emphasis is on construction and decontamination. We plan to complete 60 percent of the construction of the Vitrification Component Test Stand;

procure the test stand melter, canister turntable, and other key components; complete hardware procurement and installation and begin testing of waste mobilization and removal equipment in a one-sixth scale waste tank model; complete verification testing for supernate processing equipment; and complete decontamination of four radioactive areas and develop procedures for several more hot areas.

The funds requested for FY 1985 will be used to test and adapt installed equipment to support the beginning of supernate processing in April 1987 and sludge processing in September 1988. In particular, the program will complete and operate the Vitrification Component Test Stand; initiate design for conversion of the test stand to radioactive operation; complete decontamination of priority hot cells; and initiate procurement of supernate treatment, low-level waste treatment, and nuclear waste assay equipment.

Nuclear Waste Technology

The FY 1985 budget request for the Nuclear Waste Technology Program is $13.3 million, a decrease of $1.0 million from the FY 1984 appropriation. The funds are distributed among program elements as follows:

Program Element	FY 1984	FY 1985
	($ in Millions)	
Low-Level Waste	$ 8.2	$ 6.5
Waste Treatment	5.6	6.3
Program Direction	0.5	0.5
Total	$ 14.3	$ 13.3

Note: The FY 1984 numbers reflect comparabilities.

The goal of the Nuclear Waste Technology Program is to develop acceptable technologies for the treatment of civilian radioactive wastes. The major activities are: (1) the Low-Level Waste Program, which provides technical assistance to States to develop regional capability for the disposal of low-level radioactive waste; and (2) the Waste Treatment Program, which develops nuclear waste treatment processes and waste forms suitable for transportation, storage, and disposal in a geologic repository.

Low-Level Waste

Public Law 96-573, the Low-Level Radioactive Waste Policy Act, assigned States the responsibility for disposal of commercial low-level radioactive waste (LLW) generated within their borders. The formation of regional compacts to carry out this responsibility was encouraged by the law. The goal of the Department's LLW Program is to assist States in the development of an effective national LLW management system by 1986 and to evaluate this system in terms of operational efficiency by 1988. DOE involvement in active LLW disposal sites will also be completed by 1988.

During FY 1984, the LLW Program will complete the development of a regional LLW data base and continue its demonstration in compact regions; continue State/regional technical and financial assistance; and initiate disposal site stabilization and closure demonstrations at existing closed sites. The program is cooperating with the Office of Civilian Radioactive Waste Management to develop criteria and procedures for implementing the LLW site transfers to DOE, as called for in the Nuclear Waste Policy Act of 1982.

In FY 1985, the LLW Program will provide technical and financial assistance to a limited number of regions to support selection and operation of a new LLW disposal facility; support the correction of problems and stabilization at an existing disposal site; and support the utilization of advanced or innovative methods for the treatment of LLW.

Waste Treatment

The objective of the Waste Treatment Program is to develop and demonstrate technologies for the treatment and immobilization of nuclear fuel cycle radioactive wastes in forms acceptable for transportation, storage, and ultimate disposal in a licensed repository. Specifically, high-level, transuranic, and sodium-contaminated wastes are addressed. Over the years, methods for treating high-level and transuranic wastes have been developed. This program is now focused on determining the long-term reliability and maintainability of improved prototypical waste treatment systems and on testing and selecting acceptable waste forms for storage or permanent disposal in licensed facilities. The adequacy of these technologies is being demonstrated through their application to specific Department waste treatment efforts, such as those at West Valley and Three Mile Island. Activities in this program are coordinated with other Departmental efforts related to fuel reprocessing; generation of special wastes; transportation; and terminal isolation of Department and commercial wastes.

In FY 1984, waste solidification activities will focus on vitrification process controls and quality verification methods for demonstrating that glass waste products meet required specifications. Specifications for transuranic wastes will be completed, and transuranic waste treatment process development will continue. Criteria and guidance for shallow land burial of sodium-contaminated wastes will be field-tested and verified, with a final program report to be issued in 1985.

Activities in FY 1985 will determine the operational reliability, safety, and process control flexibility of the ceramic melter system for solidification of high-level radioactive wastes. A series of ceramic melter system design, testing, operation, and decommissioning handbooks will be developed to aid future waste treatment users. Transuranic (TRU) waste treatment technology will be evaluated and further developed. Planned activities include assessment of treatment options; evaluation of nonradioactive treatment techniques; and conduct of radioactive tests. In addition, several proposed transuranic waste treatment research and development programs involving the actual treatment of existing TRU-contaminated equipment in commercial plants will be evaluated. Evaluation of methods for treating spent nuclear fuel for interim storage and permanent disposal in a geologic repository will be initiated. Planning and evaluation of candidate materials and processes for a second generation, advanced waste form for high-level wastes from less aged nuclear wastes anticipated after the year 2000 will be conducted.

Three Mile Island (TMI)

The TMI Program is budgeted under the Converter Reactor Systems Program but is managed under the Office of Terminal Waste Disposal and Remedial Action. The objectives of this program are to acquire new information and conduct research and development that will substantially enhance nuclear powerplant safety, reliability, and operation; and to ensure the means for safe disposal of abnormal nuclear wastes resulting from an accident.

In consonance with the Administration's policy that responsibility for commercial nuclear power activities resides in the private sector, the Department's TMI Program is limited to research and development that will be of generic value to the development and safety of nuclear power and waste management. Responsibility for the costs of the TMI cleanup remain with General Public Utilities (GPU), the owner of the facility.

The TMI activities are being implemented in accordance with a Memorandum of Understanding among DOE, NRC, the Electric Power Research Institute (EPRI), and GPU. The efforts of GPU are aimed at plant cleanup and recovery. The Department has developed a program work scope that enables obtaining important research and development information that would not otherwise be available from the TMI cleanup effort. The DOE program is being conducted in a manner that avoids delaying the GPU cleanup schedule.

In accordance with a Memorandum of Understanding between DOE and NRC, the Department will acquire unique radioactive waste, including the damaged core, from TMI for research and development and for disposal. The cost of disposal will be reimbursed by GPU.

Two subprograms comprise the TMI Program: the TMI Waste Immobilization and Reactor Evaluation Program and the TMI Data Acquisition Program. The FY 1985 budget request for this program is $32.2 million, as compared with $37.0 million in FY 1984.

TMI Waste Immobilization and Reactor Evaluation. The objectives of this subprogram are: (1) to conduct research and development on immobilization of abnormal reactor waste products, and (2) to examine the TMI-2 reactor and core components in situ and to support development activities associated with the reactor defueling. The data and information acquired will provide an improved basis for evaluating licensing criteria and requirements, analyzing causes and consequences of accidents, and improving the reliability of the design and operation of light-water reactors. This subprogram was initiated in FY 1982.

The reactor evaluation activities include development associated with the examination, removal, and disposition of the reactor core and internals. This element also covers development of the special systems, equipment, facilities, and processes needed to accomplish the defueling operation, as well as performance of onsite examinations, tests, and evaluations required to handle the fuel effectively and expeditiously.

The development and engineering of systems, equipment, and procedures for removal and storage of the reactor plenum and for reactor defueling and fuel transfer will be continued in FY 1984. Removal of the reactor vessel head will be accomplished and core disassembly activities will be intensified, with the goal of removing the plenum in 1985 and starting the defueling in late 1986. The development work will be directed toward a thorough examination of the reactor internals and core. Substantial beneficial information and data on the condition of the reactor core and other internal components will be obtained. In addition, preparations will be completed to perform examinations of the fuel and debris and other reactor internal components to characterize the accident effects. The knowledge gained from this program will provide data required for evaluating present licensing criteria and requirements; developing future licensing criteria; and assessing and developing computer models used to analyze the course and consequences of severe accidents and means to mitigate the effects of such accidents; and evaluating improvements to reactor design, operation, and maintenance.

The waste immobilization activities were initially focused on an effort to demonstrate the feasibility of vitrifying zeolite ion-exchange materials. This effort was completed in FY 1983. Activities are now focusing on other techniques for the treatment of abnormal wastes produced at TMI. Long-term sample observation is being performed to provide a more extensive data base. The knowledge gained from this program will contribute substantially to the technology for processing and disposing of unique waste forms resulting from commercial nuclear powerplant abnormal operations and accidents.

TMI Data Acquisition Program. The objective of this subprogram is to obtain research and development data of generic value to the safety of light-water reactors. DOE and EPRI are sharing responsibility and costs for portions of this research and development program. Specifically, the Department is funding data gathering, research and development, and information transfer in the following major areas: instrumentation and electrical equipment survivability; behavior of radioactive products; data system and specimen archiving; and offsite fuel debris examination. EPRI has responsibility for research and development on mechanical and structural component reliability, pressure boundary recharacterization, and decontamination and dose reduction associated with the primary coolant system.

In FY 1985, DOE plans to complete the in situ and offsite examination of selected instrumentation and electrical components outside of the reactor vessel to ascertain their condition, cause of failure, and features that affect survivability. Data obtained will be used to upgrade qualification standards, regulatory guides, and operating and maintenance standards, in order to improve operation of nuclear plants and increase the likelihood of recovery from abnormal events. Efforts will continue on acquiring and analyzing solid, liquid, and gaseous samples to identify how various radioactive isotopes, which were released within the containment building during the accident, were transported and deposited. These data will be valuable in assessing the existing models for fission product release that are used in nuclear powerplant licensing. Efforts to prepare for the offsite fuel debris examination will be completed. The Technical Integration Office will continue its program management activities at the TMI site. The computer data bank system will continue to collect, store, and transfer the data and documentation generated by the DOE program during the GPU cleanup effort.

Uranium Enrichment Activities

The Department's funding request for the Uranium Enrichment Program in FY 1985 is approximately $1.7 billion in budget authority, which is fully offset by approximately $1.7 billion in projected revenue. The requested funds are distributed among the major elements of the program as indicated in the following table:

Major Program Element	FY 1984	FY 1985
	($ in Millions)	
Uranium Enrichment Activities		
Power	$1,060.0	$ 883.3
Enrichment Research and Development	189.3	150.0
Gas Centrifuge Enrichment Plant	580.5	350.0
All Other	362.2	292.0
Total	2,192.0	1,675.3
Uranium Resource Assessment	1.8	0
Total Appropriation	2,193.8	1,675.3
Uranium Enrichment Revenues	-2,105.0	-1,675.3
Net Appropriation	$ 88.8	$ 0

Note: The FY 1984 numbers reflect comparabilities.

The budget for Uranium Enrichment Activities provides funding for three major program activities: (1) Power, (2) Enrichment Research and Development, and (3) Gas Centrifuge Enrichment Plant.

Power

The United States presently enriches uranium in three gaseous diffusion plants, located in Oak Ridge, Tennessee; Portsmouth, Ohio; and Paducah, Kentucky. In FY 1985, $883.3 million is requested to purchase power for operation of the gaseous diffusion complex. The three gaseous diffusion plants will operate at a power level of 2,790 megawatts in FY 1985 and will produce about 10.6 million SWUs. The FY 1985 power level is consistent with near-term sales of enrichment services.

In past years, DOE and its contractors have expressed concerns about operating the diffusion complex at low power levels. Experience gained with low power operating procedures during the past 3 years gives us confidence that the plants can be operated safely and reliably at 2,790 megawatts. Modifications to critical instruments have extended the measurement ranges to permit monitoring of low power operation. The use of block valve throttling has been successful in restoring controllability without detrimental wear to the block valves. Other modifications are also being implemented to further improve cascade control at low power levels. In conjunction with these changes, DOE is attempting to achieve the lowest possible power costs at all three GDPs.

Enrichment Research and Development

A major objective of the Uranium Enrichment Program is to retain our competitive edge in advanced technology. This will allow us to deploy lower-cost capacity when needed to meet customer demand, and thus regain our cost-competitive position. The FY 1985 budget request includes $150 million for enrichment research and development activities, including $72 million for gas centrifuge activities. The major portion of the funding is devoted to the Advanced Gas Centrifuge (AGC) Program for further development of the Set V centrifuge, which would provide economic and technical data in support of the FY 1985 technology decision to select either AGC or AVLIS for further development through the demonstration and deployment stage. The AGC Program goal is to develop a centrifuge with production output of up to three times the output of current-generation machines. This task is technologically challenging, but if it is successful, it can substantially enhance centrifuge plant economics.

The funding requested provides for the continuation of basic development tasks; continued operation of existing Set V test facilities; and development of materials and processes for improving centrifuge separative performance.

With the centrifuge funds appropriated in FY 1984, we are: (1) producing and testing Set V machines and key subassemblies; (2) initiating high-speed full-scale rotor testing for Set V concepts; (3) establishing baseline design criteria and preliminary designs of Set V centrifuge assemblies; and (4) qualifying vendors for Set V rotor materials. Results to date on AGC have been very encouraging, and we expect to begin testing full-scale Set V machines at high speed in late 1984.

The balance of the enrichment research and development funds -- $78 million -- is requested for the AVLIS Program. AVLIS is another research and development activity to develop low-cost methods of enriching uranium. This activity is proceeding at an aggressive pace and is producing significant analytical and test results.

FY 1985 funds are requested primarily to develop and operate laser and separator facilities for the two key portions of an AVLIS production facility, which will explore process performance parameters and validate process models. As with the Centrifuge Program, FY 1985 activities in the AVLIS Program will be directed toward supplying the economic and technical data in support of the FY 1985 technology sequencing decision.

Major accomplishments recently achieved in the program include the installation of the Materials Handling Demonstration Module (MHDM) at Oak Ridge; the demonstration of source vaporization efficiency and rate in excess of plant requirements; the achievement of enrichment runs at baseline liquid alloy conditions; the design and operation of high-power lasers; and the operation of the High-Power Laser Facility (HPLF) for long run times.

Gas Centrifuge Enrichment Plant

The FY 1985 budget request contains $310 million for the construction of GCEP and $40 million for GCEP startup and operations. This project provides additional enrichment capacity using the centrifuge technology, which has the potential of significantly reducing future enrichment costs. The FY 1985 budget includes funds for continued construction of Process Buildings No. 1 and No. 2 but does not include funds for initiation of Process Building No. 3, because of near-term reductions in demand for enrichment services and the potential for introduction of more advanced Set V centrifuge machines, currently under development, into the project.

The FY 1985 funding will provide primarily for engineering of the facility to accept the Set V machine, procurement (including centrifuge machines), and construction activities on Process Buildings No. 1 and No. 2, the Feed/Withdrawal Building, and the Recycle/Assembly Building. These activities have been reduced to the minimum level necessary to maintain a viable project while retaining the flexibility to make GCEP the most economical plant possible.

GCEP is making excellent progress. Process Buildings No. 1 and No. 2 are structurally complete and enclosed, with the process equipment being installed. In Process Building No. 1, installation of the service modules is nearly complete. The first centrifuge machine was installed in November 1983, approximately 2 months ahead of schedule. In early February 1984, 106 centrifuges were in place, and three had operated successfully at full speed with uranium hexafluoride gas for test purposes. Other major facilities, such as the Recycle/Assembly Building and the Feed/Withdrawal Building, are fully enclosed, and process piping and equipment are being installed. Many of the auxiliary buildings and utility systems have been completed and turned over to the operating contractor.

In FY 1984, we expect to: (1) continue routine manufacture of centrifuge assemblies; (2) install 540 Set III centrifuges in Process Building No. 1 and have 120 centrifuges operating with uranium hexafluoride gas; and (3) continue other construction activities at a rate to achieve operation of the first train of centrifuges (720 machines) in September 1985.

All Other

The FY 1985 budget request contains $288 million for gaseous diffusion operations and support, excluding power, and $4 million for program direction. The gaseous diffusion request includes funds for diffusion operations, process and long-range technical support, supporting services, and capital equipment and construction necessary to allow operation of the three gaseous diffusion plants in the most economical, reliable, safe, secure, and environmentally acceptable manner possible. The program direction request provides funds for 69 full-time equivalent positions, including personnel services, personnel benefits, travel, and contractual services and suppliers.

Mr. Chairman, this completes my formal statement. If there are any questions regarding our programs, I would be pleased to answer them at this time.

Senator **Domenici**. Are there some Senators that want to ask questions of the Secretary?

[No response.]

Senator **Domenici**. First I'm going to ask you to answer the written questions that have been submitted by Senator Ford. Do that as soon as possible. Could we agree on maybe 10 days outside?

Mr. **Brewer**. Yes, sir. I think we can do better than that.

Senator **Domenici**. And Senator Johnston may have a few. We will get those to you today or tomorrow, and if you could answer them on that same timeframe, so we will know how to close the record. If you run into some problems let us know, so we can extend the time.

In your testimony today you say that you expect to complete remedial action plans for mill tailings cleanup at a number of sites, including Shiprock—that's in New Mexico. Your statement says, "I'll be done during this fiscal year."

The budget request for 1985 also includes—beginning at that site, could you tell me what the status as of now is of the debate of whether or not to stabilize the mill tailings in place or move them from their present site?

Mr. **Brewer**. Senator, yes, I can. An agreement has been reached with the local government. It's my understanding that the Shiprock Community Chapter, Navajo Nation has urged us to stabilize the site in place. And I would like to offer for the record the Resolution that so affects that recommendation to the Department by the——

Senator **Domenici**. Navajo Tribal Council?

Mr. **Brewer**. Yes, sir; the Shiprock Community Chapter Navajo Nation, New Mexico.

Senator **Domenici**. All right. We will make that part of the record.

[The resolution follows:]

PROPOSED RESOLUTION
OF THE SHIPROCK COMMUNITY CHAPTER

The Shiprock Community Chapter Directs That The Shiprock Uranium Mill Tailings Pile Be Stabilized At Their Present Location By The U.S. Department of Energy

WHEREAS:

1. The unstabilized uranium mill tailings pile located close to the Shiprock fairgrounds poses a threat to the health and safety of residents of the Shiprock community in its present condition; and

2. The uranium mill tailings pile poses an equally serious threat to the environment; and

3. Many different alternatives have been considered regarding ways to make the tailings pile safe; and

4. The United States Department of Energy has conducted extensive tests and studies on all options for the clean up of this serious problem, and has determined that the tailings pile could be stabilized in place, thereby reducing health and safety risks and adverse environmental impacts to an acceptable level; and

5. Removal of the tailings pile would create even more environmental damage and risk to the health and safety of the Shiprock community due to:

   (A) The increase in traffic.

   (B) An increase in potential accidents involving transportation of the radioactive materials.

   (C) The longer time required for clean up.

   (D) The delay in the scheduled date for clean up work to begin; and

6. Clean up of the Shiprock uranium mill tailings pile will create employment opportunities for the Navajo people and increased economic benefits to the community, and

NOW THEREFORE BE IT RESOLVED THAT:

1. The Shiprock Community Chapter hereby endorses clean up of the uranium mill tailings pile near the Shiprock fairgrounds in a manner which will protect the health, safety, and environment of all people in the Shiprock community; and

2. The uranium mill tailings should not be removed from their present location, but should instead be stabilized at their present location; and

PROVIDED THAT:

1. During the course of clean up work, the Department of Energy or its contractors utilize to the maximum extent possible, local labor to perform the necessary work; and

2. The remedial action design provides to the maximum degree possible, compatability with present and future land use activities of the area adjacent to the tailings pile,

3. It is understood that certain design features that are required as a part of the remedial action may also provide opportunities for post-remedial action use by the Shiprock Community, and therefore will be designed and provided with that understanding in mind.

CERTIFICATION

I hereby certify that the foregoing resolution was duly considered by the Shiprock Community Chapter at a duly called meeting at Shiprock, Navajo Nation (New Mexico) of which a quorum was present and that same was passed by a vote of 86 in favor and 1 opposed, this 16th day of MARCH, 1984.

Chairman
Shiprock Community Chapter

Council Delegate
Shiprock Community Chapter

Vice President
Shiprock Community Chapter

Secretary
Shiprock Community Chapter

Senator **Domenici**. So that as the local jurisdiction, they are satisfied with it being stabilized there. They must have been advised as to the process, I assume?

Mr. **Brewer**. Yes, sir.

Senator **Domenici**. And they're satisfied with that also?

Mr. **Brewer**. Yes, sir. I'm holding in my hand a resolution by the tribal council and signed by Shiprock Community Chapter chairman and three members.

Senator **Domenici**. So what's next on that, as it is your understanding?

Mr. **Brewer**. Well, we have signed a memorandum of understanding or cooperative agreement, if you will, with the Navajo Nation. They have expertise in terms of earth-moving experience.

We have in the 1983 budget, this past year, about $400,000 for planning and environmental analysis. In the 1984 budget we have about $1.8 million for completing the remedial action plan and the engineering design, and in the proposed budget for this year we have $5.7 million to actually begin and complete 60 percent of the remedial action.

We have to complete the environmental impact statement to support a decision as to the method of stabilization.

Senator **Domenici**. We have one more question, then I'll submit two or three in writing. But let me ask, are all four of our public witnesses here? Dr. Harold Agnew, I see you.

Mr. Walker, from Gas-Cooled Reactor, San Diego?

[Hand raised.]

Senator **Domenici**. David M. Berick, nuclear waste project, Environmental Policy Institute?

[Hand raised.]

Senator **Domenici**. And Frederick Webber?

[Hand raised.]

Senator **Domenici**. OK. We are going to move to you quickly, because I know some of you have come from a distance.

Let me just recap with you a question, Mr. Secretary. This committee recently included some language in their report to the Budget Committee about the way the Department is modifying its nuclear programs, specifically the breeder program. Obviously, after last year, this assessment seems to be necessary. Obviously, the committee thought it was—not this subcommittee, the full committee.

I'd like to put the language we have in the budget report in the hearing record today, and would like to stress to you some points in that language and to get your brief comments.

We're aware that you're under a great deal of pressure by some to drastically change the direction of your research program and your development program in the nuclear area generally. Pressures for research on smaller reactors and fuels cycles are strong. You're aware that a number of individuals and groups believe that the status quo is the only route to follow.

I think a number of us on this committee believe that neither extreme is the right course. What we've tried in our language is to stress that the Department ought to survey the utilities and the industries at large for what they want and what new ideas are available. We also think you should then set up a series of goals for your research and development program that could be measured against each other. We think that a very quantitative system in this regard would be helpful. I would just ask you what you think about that approach?

Mr. **Brewer**. Senator, that's completely in accord with our plans.

Senator **Domenici**. Then you are aware of that kind of direction, and you're telling the committee through this subcommittee that you're going to try to do that?

Mr. **Brewer**. Yes, sir.

Senator **Domenici**. Before we go to the public witnesses, we have to hear from Mike Lawrence, Acting Director of the Office of Civilian Waste Management. So let's do that right now.

Senator **Johnston**. Mr. Chairman, I would like to say, if I may interrupt.

Senator **Domenici**. Of course.

Senator **Johnston**. I think the Secretary is aware of my concerns particularly on the monitored-retrievable storage program. And I hope members of the committee will take a look at what the Department is doing. I don't think it will satisfy the public, and I don't think it satisfies the intent of the law: that is, adopting the open filed dry well concept—putting the cask in the sand. I hope you all will take another look at that.

Senator **Domenici**. And our next witness will address that issue, Mike Lawrence, from the Office of Nuclear Waste.

We are pleased to hear from you. Your written statement will be made a part of the record. Proceed, please.

STATEMENT OF MICHAEL J. LAWRENCE, ACTING DIRECTOR, OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT, DEPARTMENT OF ENERGY

Mr. **Lawrence**. Thank you, Senator. And I, too, will try to be very brief.

Since the signing of the Nuclear Waste Policy Act last year, the Office of Civilian Radioactive Waste Management reporting to the Secretary has been put into place and is operating.

Seventy contracts with 56 utilities or other organizations have been signed, and have generated $235 million of revenues through February 1984.

Last year we identified potentially acceptable sites for the first repository, and notified 17 States that they contain formations under consideration for a second repository. We developed siting guidelines and sent them to NRC for concurrence.

The NRC is currently considering those guidelines and, if they concur by May, which is their current anticipation, then we believe that by the end of this year we can issue environmental assessments, nominate at least five sites and recommend three for the development of the first repository by January 1, 1985, as required by the act.

We also believe that if this proceeds, we can have a geologic repository in place to begin accepting waste by 1998; another key milestone in the act.

With regard to the monitored retrievable storage program, sir, we have submitted a report to the Congress on research and development activities associated with that program. We have selected the architect-engineer to do the detailed proposal due to Congress next year, and the concepts have been selected. We will have a proposal to Congress by June 1, 1985, to develop MRS facilities as an option to geologic disposal.

Finally, in the area of spent-fuel storage. The Federal interim storage reports and documents required by the act dealing with the fees that the Federal Government would charge for interim storage and its plan for providing Federal storage, if it were necessary, have been submitted to the Congress. However, because of the success that we anticipate with the cooperative demonstrations, with Virginia Electric & Power Co. [VEPCO], Carolina Power & Light, and Northeast Utilities Co., which are planned for 1985, it's our anticipation that no Federal interim storage will, in fact, be necessary.

Finally, we are conducting storage demonstrations with the Tennessee Valley Authority for Brown's Ferry and the development of transportable storage casks with the Nuclear Fuel Services Co. And it's these activities which give us confidence that, by the end of this decade, the NRC will be able to license new storage techniques to enable our utilities to meet their storage needs prior to the availability of a Federal system for storage and disposal in 1998.

So I would be happy to answer any questions you or the other Senators have.

[The prepared statement of Mr. Lawrence follows:]

STATEMENT OF MICHAEL J. LAWRENCE

ACTING DIRECTOR
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

DEPARTMENT OF ENERGY

BEFORE THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

MARCH 22, 1984

Mr. Chairman and Members of the Subcommittee:

I am pleased to appear before you today to discuss the Department of Energy's (DOE's) Fiscal Year 1985 commercial nuclear waste management and spent fuel storage budgets and programs. The FY 1985 budget represents the first budget formulated by the Office of Civilian Radioactive Waste Management, recently established under the Nuclear Waste Policy Act of 1982.

The FY 1985 budget presents an integrated picture of programmatic activities including: repository deployment, monitored retrievable storage development and fund management which are specifically financed by fees collected from utilities and placed into the Nuclear Waste Fund; and, research and development activities not eligible for financing under the Nuclear Waste Fund, including research and cooperative agreements on spent fuel and research on alternative disposal concepts. These latter activities are funded under Energy Supply Research and Development in a program entitled Civilian Radioactive Waste Research and Development (R&D).

The FY 1985 budget request for obligational authority funded by the Nuclear Waste Fund is $327.669 million.1/ This budget request is summarized in Table 1. The FY 1985 Departmental budget request for Energy Supply R&D, which covers activities not eligible for funding under the Nuclear Waste Fund, is $27.64 million. This budget is summarized in Table 2.

The $327.669 million requested will be used to fund the activities under the direction of the Office of Civilian Radioactive Waste Management. These activities are fashioned on the fundamental objective of the Nuclear Waste Policy Act of 1982 (NWPA), which is:

> "to accept high-level radioactive waste for safe management, storage and permanent disposal on a firm schedule, beginning not later than January 31, 1998."

By achieving this fundamental objective and implementing an appropriate waste acceptance schedule, this will initially preclude the need for additional at-reactor storage by nuclear utilities after January 31, 1998, and, ultimately, remove all eligible waste from at-reactor storage.

1/ The NWPA requires the Secretary to submit a triennial budget for the Nuclear Waste Fund. The discussion of specific activities presented in the Waste Fund Program gives estimates for FY 1986 and FY 1987. The estimates for the total Waste Fund Program are: FY 1986 - $525.4 million; FY 1987 - $528.6 million.

TABLE 1

FY 1985 CONGRESSIONAL BUDGET
NUCLEAR WASTE FUND
(Budget Authority In Thousands)

	FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
NUCLEAR WASTE FUND			
Repository Deployment			
o First Repository	$192,537	$246,560	$247,100
o Second Repository	12,322	16,270	28,700
Monitored Retrievable Storage	3,499	12,000	8,500
Program Management and Technical Support	7,175a/	40,091b/	40,069
Debt Service (Interest)	3,067	4,700	3,300
TOTAL	$218,600a/	$319,621b/	$327,669
Projected Receipts	(73,600)	(310,600)	(377,800)
Staffing FTE's	110	204	236

a/ Includes comparability adjustments of $1,275,000 for FTE's reassigned for other Departmental activities.

b/ Includes comparability adjustments of $946,000 for FTE's reassigned from other Departmental activities.

TABLE 2

FY 1985 CONGRESSIONAL BUDGET
ENERGY SUPPLY RESEARCH AND DEVELOPMENT ACTIVITIES
(Budget Authority In Thousands)

	FY 1983 Approp.	FY 1984 Approp.	FY 1985 Request
Civilian Radioactive Waste R&D			
Spent Fuel Storage R&D	6,389	5,000	13,200
Alternative Disposal Concepts	6,000	4,700b/	12,000
Generic Methods and Supporting Studies	17,875a/	1,600	2,174
Program Direction	130	130	266
TOTAL	$30,394	$11,430	$27,640

a/ Reflects adjustment of $125,000 transferred, to the Office of Energy Research for Small Business Innovative Research efforts in accordance with P.L. 97-219.

b/ Excludes $2,800,000 reprogramming from other DOE accounts accordance with Congressional directive in the Conference Report, H. Report 98-272, to P.L. 98-50.

Before discussing the details of the FY 1985 budget request, I would like to briefly give an overview of what we have accomplished since enactment of the Nuclear Waste Policy Act of 1982 and the mandated milestones that we have not met; the organization alignment for carrying out the responsibilities of Civilian Radioactive Waste Management; and the basic program strategy.

OVERVIEW

Accomplishments Since Enactment of the NWPA

Much has been accomplished in the 13 months since enactment of the NWPA on January 7, 1983. However, this also has been a period of organizing, reorienting and redirecting the Federal Government's nuclear waste management efforts under the new law.

The NWPA sets forth an unusually precise and complex schedule of tasks that must be accomplished and a set of procedures that must be followed. During the past 13 months, the NWPA required that the following major demanding tasks be accomplished:

- Within 90 days of enactment, identify states with one or more potentially acceptable repository sites and notify the Governors, the state legislatures, and the Tribal Councils of any affected Indian tribes in such states;

- Within 90 days of enactment, publish a joint Department of Energy/Nuclear Regulatory Commission (DOE/NRC) notice in the Federal Register that the United States is prepared to cooperate with and assist non-nuclear weapon states in at-reactor and away-from-reactor fuel storage, monitored retrievable spent fuel storage, geologic disposal of spent fuel, and the health, safety, and environmental regulation of such activities;

- Not later than 90 days after enactment, establish a one-time fee per kilogram of heavy metal in spent nuclear fuel or in solidified high-level radioactive waste existing prior to April 7, 1983;

- Not later than 180 days after enactment, establish fee collection and payment procedures;

- By June 30, 1983, enter into contracts with all owners and generators of spent nuclear fuel or high-level radioactive waste;

- Within 180 days of enactment, establish payment charges for Federal Interim Storage Services;

- Not later than 180 days after enactment, issue general guidelines for recommending repository sites;

- Not later than six months after enactment, submit to Congress a report describing the essential research and development needed to develop a proposal for a monitored retrievable storage facility;

- Not later than one year after enactment, select at least 1, but not more than 3, civilian nuclear power reactor sites to conduct a demonstration program, in cooperation with the private sector, for the dry storage of spent nuclear fuel;

- Within one year of enactment, submit a report to Congress with respect to alternative approaches to managing the construction and operation of all civilian radioactive waste management facilities, including the feasibility of establishing a private corporation;

- Annually prepare and submit to Congress a report on any plans for providing interim storage capacity;

- Submit an annual report to Congress on the activities and expenditures of the Office of Civilian Radioactive Waste Management;

- Not later than one year after enactment, transmit to Congress a report setting forth whether the Secretary plans to colocate a test and evaluation facility (TEF), if built, with a repository.

Of these 13 tasks, 10 have been completed on or before schedule. One, the TEF report, will be several weeks late and only two have not been met:

(1) issuing general repository siting guidelines; and, (2) submitting a report to Congress on alternative approaches to managing the construction and operation of all civilian radioactive waste management facilities. The status of these two tasks is as follows:

(1) Siting Guidelines

As previously stated, the NWPA requires that DOE issue general guidelines for recommending repository sites within 180 days of enactment, and that these guidelines be developed in consultation with the Council on Environmental Quality, the U.S. Environmental Protection Agency, the U.S. Geological Survey and interested Governors. In addition, these siting guidelines are to be concurred in by the NRC. We have not as yet issued final guidelines.

In February 1983, DOE published draft guidelines. Public Hearings were held and written and oral comments were received. DOE met with representatives from affected and interested states to discuss the guidelines and to answer questions. More than 2,000 individual comments were received. An alternative guidelines document was issued to incorporate many of the comments and suggestions received. A second public comment period was provided. Due to this expanded consultation process, the 180-day deadline for issuing final guidelines passed.

After the close of the second comment period, which resulted in 900 additional comments, draft final guidelines were prepared and provided to the states. Following a plenary state consultation meeting and further revisions, the states were also given copies of a final internal review draft and invited to comment on important remaining issues. Final guidelines were subsequently forwarded to NRC for review and concurrence on November 22, 1983. NRC held a hearing on the guidelines January 11, 1984. Upon receipt of concurrence by NRC, DOE will issue final siting guidelines.

It is DOE's belief that the importance of full consultation with states and the need for public comment on the general guidelines to be used for recommending repository sites has warranted the delay in issuance.

(2) Report to Congress on Alternative Approaches to Managing

The NWPA requires the Secretary to undertake a study with respect to alternative approaches to managing the construction and operation of all civilian radioactive waste management facilities, including the feasibility of establishing a private corporation.

On December 16, 1983, the Secretary appointed an advisory panel to undertake this study. The panel is made up of thirteen representatives of State governments, Indian Tribes, private industry and the general public and has been charged with studying alternative means of financing as well as managing the problem. The panel's recommendations to the Secretary are expected to be completed by October 15, 1984 and the report will be submitted to Congress on or about December 31, 1984.

The organization within DOE which has been carrying out the waste management responsibilities since enactment of the NWPA is described below.

Organization

The NWPA called for the establishment of the Office of Civilian Radioactive Waste Management to be headed by a Director appointed by the President, by and with the advice and consent of the Senate. It is my understanding that the Secretary has recommended to the White House a candidate for Director.

Shortly after passage of the Act, however, the Secretary established a temporary project office to carry out the near-term requirements of the Act until the formal office could be activated. In October 1983, the Secretary formally approved and activated the permanent Office of Civilian Radioactive Waste Management (OCRWM).

The permanent organization has been divided into four major functional components. These four functional components closely align with those laid out in the Act. They are:

- Geologic repository activities;
- Storage and systems development activities;
- Management and management support functions; and
- Overall program direction and institutional relations.

The primary function of the Office of Geologic Repository Deployment is to site, design, construct, operate, and decommission the radioactive waste disposal facilities. It is also responsible for screening and characterizing potential geologic repository sites; recommending sites; conducting field tests including in-situ tests via exploratory shafts; developing waste emplacement packages; preparing documents to meet all regulatory, licensing, safety, environmental and quality assurance requirements; cooperating with State and Indian tribes; evaluating the need for and designing a test and evaluation facility; and managing the research and development of disposal technology for both repositories and alternative means of permanent disposal.

The Office of Storage and Systems Development manages the activities related to interim storage and any associated R&D efforts; monitored retrievable storage; waste packaging and handling; and transportation systems.

The Office of Management administers the Nuclear Waste Fund, the Civilian Radioactive Waste R&D Program, and, if activated, the Interim Storage Fund. It is also responsible for overall planning; budget preparation; financial management, management information, including personnel; and, data systems.

The Institutional Relations Staff has primary responsibility for developing and coordinating OCRWM's institutional and external relations.

Attachment 1 depicts the overall Headquarters organization structure and major responsibilities. Attachment 2 depicts the functional alignment.

Program Strategy

DOE is required to prepare a comprehensive Mission Plan to serve as a means of both planning the program and demonstrating its conformance to the requirements of the NWPA.

The Mission Plan will consist of two volumes. Volume I will be the plan for conducting the civilian radioactive waste management program, including discussion of the program's policy, strategy, plans and intended schedule. Volume II will include more detailed information to address the items specifically required by the Act, including an identification of the primary scientific, engineering and technical information; an evaluation of financial, political, legal or institutional problems that may impede implementation of the Act and plans to resolve such problems; and identification of the possible adverse economic and other impacts to the State or Indian tribe involved that may arise, from the development of a repository at a site.

An advanced copy of Volume I of the draft Mission Plan was sent in late December 1983 to the Nuclear Regulatory Commission and other Federal agencies, the Congress, State governments, affected Indian tribes, utilities and nuclear industries.

Volume II is currently being prepared. When completed, and as required by the Act, both Volumes of the draft Mission Plan will be released to interested parties, as well as to the general public, for review and comment by April 7, 1984.

When finalized in mid-1984, the Mission Plan will be submitted to Congress.

As set forth in the draft Mission Plan, DOE will pursue four major program goals:

1. Site, design, construct and operate the first mined geologic repository by January 31, 1998.
2. Design an engineered Monitored Retrievable Storage facility, on a schedule that will permit its timely construction, if authorized by Congress.
3. Assist utilities in providing adequate, safe at-reactor storage of spent fuel and stand ready to provide limited Federal Government storage to utilities if they are determined qualified by the Nuclear Regulatory Commission.
4. Manage the technical program and the funds collected for disposal and storage services, in an effective and efficient manner.

DOE plans to carry out this program with full adherence to the legislated institutional process, while developing sound technical data needed to support key milestones and decision points.

To accept high-level radioactive wastes for safe management, storage and permanent disposal beginning not later than January 31, 1998, a demanding set of technical, regulatory and institutional challenges will have to be met. With these challenges in mind, we have formulated the FY 1985 budget request that we are presenting to you today.

I would like to highlight some of the major elements of the FY 1985 program. The discussion is divided into two parts which coincides with the two separate budgets managed by the Office of Civilian Radioactive Waste Management: The Nuclear Waste Fund Program; and the Civilian Radioactive Waste Research and Development Program.

THE NUCLEAR WASTE FUND PROGRAM

Revenue Sources

The NWPA established the Nuclear Waste Fund to finance the waste disposal program. The Fund receives all the revenue the DOE collects from the nuclear utilities under the disposal services contract.

The main source of revenue for the Fund is the one mill per kilowatt hour fee charged for all electricity generated by civilian nuclear reactors beginning April 7, 1983. The NWPA provides for annual review and adjustment to assure that the fee is sufficient to recover all program costs.

A preliminary review and evaluation of this fee was undertaken during FY 1983 to determine if the one mill fee is sufficient to meet the full cost recovery mandate. The resulting report published in June 1983, estimates total system life cycle costs at nearly $20 billion in constant 1982 dollars.

Additional work on the fee adequacy was initiated in July 1983 to prepare for the next annual review to be published in July 1984. Based on the latest forecasts of the Energy Information Administration, revenue projections are declining. The near-term impact of the lower revenues could constrain the program. Therefore, the revenue projections contained in our FY 1985 budget now assume the 1 mill per kilowatt hour fee will be escalated to the rate of 4.7 percent in FY 1985 and 4.5 percent in FY 1987. DOE is still evaluating these estimates and will make its final recommendation in July 1984 when the annual Fee Adequacy Report is due to Congress.

Assuming that the 1 mill per kilowatt hour fee is escalated as described above, revenue projections are as follows:

NUCLEAR WASTE FUND REVENUE PROJECTIONS
(In Thousands)

FY 1983	FY 1984	FY 1985	FY 1986	FY 1987
$73,600	$310,600	$377,800	$435,000	$504,300

High-level radioactive waste and spent fuel generated prior to April 7, 1983, is subject to a one-time fee per kilogram of heavy metal in such spent fuel or high-level waste. The fee must be equivalent to an average charge of one mill per kilowatt hour. The utilities have three options for paying this fee and must decide by June 1985 on the option they select. Until then, it is not possible to predict when these revenues will be available to the Fund. However, the one-time fee is estimated to be $2.3 billion now and will increase as interest is applied to the fee if the utilities choose to defer payment.

The Nuclear Waste Policy Act also requires the Department to evaluate the use of disposal capacity at one or more repositories for the disposal of high-level radioactive waste resulting from atomic energy defense activities. This study which is funded from the Defense appropriation is due to be completed in January 1985. If the Department decides to recommend disposal of the defense waste in a commercial repository, the Federal Government would pay for disposal of that waste in the repository.

Program activities funded by the Nuclear Waste Fund include: the geologic repository deployment programs; monitored retrievable storage; transportation; and program management and technical support. I would now like to highlight some of the major elements in those areas and in the FY 1985 budget request.

Repository Program

A. First Repository

The draft Mission Plan highlights a repository program divided into three phases. Phase 1 is Site Screening, Phase 2 is Site Characterization, and Phase 3 is Site Licensing and Construction. The current schedule for achieving major milestones within these three phases and associated with the first repository is as follows:

Phase 1

o Identification and Notification of Potentially Acceptable Sites (nine)	February 1983
o Issuance of Final Siting Guidelines	June 1984
o Issue Draft Environmental Assessments	Summer 1984
o Issue Final Environmental Assessments on five or more sites to be nominated	Fall 1984
o Nominate five or more sites as Suitable for Site Characterization and Recommend 3 Sites for Site Characterization	By January 1, 1985

Phase 2

o President Approve Sites for Characterization	March 1985
o Issue Site Characterization Plans for 3 Sites	March 1985
o Begin Exploratory Shaft Construction	March 1985
o Recommend First Repository to President	December 1990

Phase 3

o President Recommend Site to Congress	February 1991
o Submit Construction Application to NRC	February 1991
Receive Limited work Authorization	August 1991
Receive full authorization	February 1994
o Begin Repository Operation	January 1998

The FY 1985 budget request for activities associated with the first repository is $247.1 million. The FY 1986 estimated is $427.1 million; and the FY 1987 estimated is $403.2 million.

The FY 1985 activities included in the $247.1 million are as follows:

- o Recommend three sites for site characterization for the first repository and begin detailed geologic, environmental and socio-economic studies and evaluations of those sites. Activities would include drilling and coring operations to better understand site stratigraphy and tectonics; comprehensive evaluation of site and regional geohydrology; other geotechnical analyses, such as seismicity, geochemistry and volcanism. ($58.2 million)

- o Begin construction of and preparation for exploratory shafts at up to two of the three candidate sites and begin planning for performance of in-situ tests. ($56.2 million)

- o Conduct site-specific engineering studies at the three recommended candidate sites consisting of evaluations of rock mechanics, shaft and tunnel excavation methods, equipment development, waste emplacement alternative methods and repository design studies. ($37.4 million)

- Conduct other engineering studies and analyses to determine the behavior of materials being considered for waste packages, develop test facilities for testing the performance of component materials and designs, and develop models and computer codes to ensure the engineered systems and the site will perform individually as well as collectively for overall repository performance. These studies will assist in the development of the necessary planning and licensing documents required by the NWPA and the Nuclear Regulatory Commission. ($85.7 million)

- Continue Federal/State assistance to States and Indian tribes so that they can participate in the repository plans and activities. These funds are provided to allow States and Indian tribes to study, determine, comment on and make recommendations on possible health, safety, environmental, social and economic impacts of a repository. ($9.6 million)

The FY 1986 and FY 1987 estimates of $427.1 million and $403.2 million, respectively, will support concurrent full site characterization efforts at all three recommended repository sites, shaft procurement and construction at those sites and enhanced site-specific waste package and repository engineering and design efforts.

B. Second Repository

Although construction of a second repository has not been authorized, the NWPA sets forth a schedule for siting a second repository. The activities for siting and designing a second repository include the same processes as for the first repository. The second repository program is being conducted so that the four-and-a-half year lag time between the recommendation of sites for site characterization for the first repository and the recommendation of sites for site characterization for the second repository will be preserved to the maximum extent possible.

The siting process for the second repository is presently in the regional characterizaion phase in which DOE is conducting studies in 17 states in media such as crystalline rock in the North Central, the Northeastern and the Southeastern parts of the United States.

The current schedule for achieving major milestones within the second repository program is as follows:

Phase 1

o Identification and Notification of Potentially Acceptable Sites	Summer 1985
o Issue Draft Environmental Assessments	Fall 1988
o Issue Final Environmental Assessments	Spring 1989
o Nominate and Recommend Sites for Site Characterization	Fall 1989

Phase 2

- President Approve Sites for Characterization — Fall 1989

Phase 3

- President Recommend Site to Congress — Summer/Fall 1995

The FY 1985 budget request for activities associated with the second repository is $28.7 million. The FY 1986 estimate is $50.6 million; and the FY 1987 estimate is $75.6 million.

The FY 1985 activities included in the $28.7 million are as follows:

- Continue development of a data base for studies in crystalline rock formation.
- Complete and issue draft crystalline rock area recommendation reports.
- Complete and issue draft crystalline rock area characterization plan.
- Identify potentially acceptable sites and notify States.
- Review of existing repository conceptual designs from the salt, basalt and tuff programs, along with review of repository designs for crystalline rock from the Swedish, Canadian and Swiss programs.

- Continue tests at th Stripa mine in Sweden and the Colorado School of Mines.

- Initiate testing at the Canadian Underground Research Laboratory and prepare plans and instrumentation for testing in the Climax facility in Nevada.

- Continue Federal/State assistance.

The FY 1986 and FY 1987 estimates of $50.6 million and $75.6 million, respectively, will support field investigations, including drilling of one or more boreholes, which will be completed in summer 1987.

To supplement repository site characterization and to resolve repository engineering and licensing issues identified through the licensing application review process, the NWPA authorizes DOE to build a Test and Evaluation Facility (TEF). The following is a discussion of the status of DOE's activities regarding a TEF.

Test and Evaluation Facility

DOE has evaluated the role and location of a TEF with respect to its potential benefits to the repository program. At this time, DOE believes that the acquisition of additional site specific information, if needed in the repository program, can best be achieved by developing a collocated TEF. Our current plans are to make a decision in late 1987 on the need for a collocated TEF. No funds are requested in FY 1985.

At this time, it is uncertain what role the additional site specific data will play in the program and their degree of importance, relative to the data acquired during the site characterization phase. To a large extent, this uncertainty will diminish as the site characterization plans for the three candidate repository sites are prepared and submitted, reviewed by the NRC, and updated as more is learned about the sites and feedback from the NRC is incorporated into the program. By late 1987, according to the current repository schedule, five updates to the initial site characterization plans will have been prepared and issued, and initial test planning to aid in determining data needs will be well along. At that time, DOE will be in a better position to decide on the need for a collocated TEF.

I would like now to discuss our plans regarding the study of the need for and feasibility of an MRS.

Monitored Retrievable Storage

The near-term objective of the MRS program is to prepare and submit a proposal to Congress on or before June 1, 1985, for the construction of one or more MRS facilities. The FY 1985 budget request to support the MRS program is $8.5 million. The FY 1986 and FY 1987 estimates of $1.5 million, assume maintaining the MRS option without proceeding toward deployment.

In FY 1983, DOE prepared a report to Congress describing the research and development activities necessary to develop a MRS proposal. This report concluded that "no further research and development activities are considered necessary to develop a MRS proposal as required by the Nuclear Waste Policy Act of 1982."

The proposal due to Congress June 1, 1985, will be based on a detailed study of the need for and feasibility for one or more MRS facilities. The study will include detailed designs, specification, and cost estimates in sufficient detail to support Congressional consideration for authorization of such facilities.

In October 1983, an Architect/Engineer was competitively selected to do the designs and plans necessary for the proposal. In the development of the MRS proposal, prime consideration will be given to safety and flexibility of the design concepts. The selected concepts have inherent safety features and are considered among the safest concepts considered. Since actual deployment of an MRS is dependent upon congressional authorization which will include, among other factors, the status and timing of the geologic repository program, flexibility is a key consideration in the MRS concept selection. The sealed storage cask and the open field drywell concept were selected. Both concepts are modular, capable of being designed and built with a small initial capacity but expanded as necessary with a minimum of lead time and cost penalty. Both concepts can also readily accommodate either spent fuel or solidified high level waste. These two design concepts will be developed as potential concepts for three potential sites.

In FY 1985, the design efforts will be completed, culminating in the presentation of the Proposal to the Congress. In addition, in FY 1985, a siting plan to be included in the proposal will be completed based on criteria and siting approach developed in FY 1984. Also, as required, an Environmental Assessment document will be completed and submitted to Congress with the MRS proposal along with a plan for integrating the MRS with the other authorized storage and disposal facilities.

The FY 1986 and FY 1987 estimates of $1.5 million each year will provide for proposal follow-up and updating of designs to respond to technology or requirements changes. Should the Congress decide to proceed with authorization of an MRS, activities in FY 1986 and beyond would include preparation of an Environmental Impact Statement, selection of an Architect/Engineer and Construction Management team, initiation of Title II design, site related activities, etc. However, additional funding would be required in FY 1986 and in FY 1987.

Program management and technical support is required to support the management of the Nuclear Waste Fund, the repository program and monitored retrievable storage programs as well as to integrate these programs. I would like now to briefly describe those requirements for FY 1985.

Program Management and Technical Support

The FY 1985 budget request for program management and technical support is $40.069 million. The FY 1986 estimate is $41.0 million and the FY 1987 estimate is $41.3 million.

The FY 1985 funding level of $40.069 million will support the following activities:

- Continue technical contractor support for conducting safety and design reviews; coordinating and developing licensing documentation; technical assistance support in program analysis and system engineering, cost trade-off studies, reviewing site characterization plans, reviewing environmental assessments; and reviewing design of shafts, surface facilities, and underground excavation for a repository and assisting DOE in coordinating the overall civilian radioactive waste management program. ($9.6 million)

- Develop standard material test methods; analyze repository transporation needs; and maintain inventory of spent fuel for future test programs and calculate fees. These activities include maintenance of the Engineer Maintenance Assembly and Disassembly (E-MAD) facility; development of standard materials characterization methods by the Material Characterization Center (MCC); transporation studies and systems integration analysis for the disposal program; and other supporting studies including fund management activities. ($14 million)
- Provide for a total of 236 Federal full-time equivalents (FTE's) for positions in the field and at Headquarters to manage funding, site investigation, technology development and institutional liaison required to obtain State, NRC and Presidential decisions for repository siting, MRS and supporting programs. ($16.469 million)

The FY 1986 and FY 1987 estimates of $41.0 million and $41.3 million, respectively, will provide for increased and continuing technical support in reviewing and updating the site characterization plans and for additional manpower to review site selection documents.

Debt Service

Debt Service in the budget request identifies the estimated interest expenses that the Nuclear Waste Fund will accrue. When the Nuclear Waste Fund was established in FY 1983, the NWPA required the Department to transfer all unexpended balances to the Fund which were previously appropriated under the Energy Supply Research and Development account for Fund activities. This transfer totaled $254 million. These funds are to be repaid with interest to the General Funds of the Treasury.

The FY 1985 Debt Service (Interest) requirements are $3.3 million. The FY 1986 estimates are $5.2 million; and the FY 1987 estimates are $7 million.

The Waste Fund is allowed to earn interest on funds in excess of outstanding Treasury debt. The current and expenditure projection indicate that liquidation of the debt will not occur prior to FY 1989. However, if the Department receives the lump sum payments of approximately $2.3 billion for spent fuel discharged prior to April 7, 1983, the Department might ask for supplemental budget authority to liquidate the debt sooner. Because the nuclear utilities have three payment options, two of which defer payments with interest, DOE cannot anticipate what monies will be received until the date upon which they must select the option, June 1985.

This concludes my discussion of the activities under the Nuclear Waste Fund Program; I would like to now to discuss the Civilian Radioactive Waste R&D Program which is comprised of generic research and cooperative agreement activities consistent with the NWPA but not eligible for funding through the Nuclear Waste Fund.

CIVILIAN RADIOACTIVE WASTE RESEARCH AND DEVELOPMENT PROGRAM

The NWPA requires the Secretary to budget for spent fuel storage R&D; alternative disposal concepts (subseabed) and generic repository research, development and demonstration activities under the Energy Supply R&D appropriation rather than funds collected from the utilities and deposited into the Nuclear Waste or Interim Storage Fund. DOE has established a new decision unit entitled Civilian Radioactive Waste R&D to accommodate both the existing R&D activities and those pertinent to generic research and waste management initiatitves under the NWPA. As previously, mentioned, the FY 1985 budget request for the Civilian Radioactive Waste R&D activities is $27.64 million.

I would like to briefly discuss the highlights of the activities which we plan to undertake in FY 1985.

Spent Fuel Storage R&D

Spent Fuel Storage Research and Development consists of R&D activities supportive of the NWPA which mandates the Secretary to take such actions as necessary to encourage and expedite the effective use of available storage and necessary additional storage at each civilian nuclear power reactor. The FY 1985 budget request to support these activities is $13.2 million.

FY 1985 activities include the following:

- o Perform tests and analyses to determine the conditions under which spent fuel can be safely stored, and to determine the means to assure that the safe conditions are not exceeded in various applications.

- o Continue a joint DOE/Tennessee Valley Authority cooperative demonstration of licensed storage of spent fuel in two dry storage casks.

- o Continue a joint DOE/Nuclear Fuel Services cooperative demonstration to transport spent nuclear fuel in a dry storage cask, store and test fuel and reship later in the same cask. This activity will be initiated in FY 1984.

- As required by Section 218 of the NWPA, participate with utilities and industry in the demonstration of new storage technologies to provide a data base for future NRC licensing actions. Three utilities were competitively selected in October 1983 to participate in either dry storage technology or rod consolidation at-reactor demonstrations. The three utilities are Virginia Electric and Power Company (VEPCO), and Carolina Power and Light (CP&L) which will participate in dry storage technology demonstrations; and Northeast Utilities Services Company (NUSCO) which will participate in a rod consolidation demonstration. These cooperative demonstrations are currently being negotiated. Demonstrations will begin during FY 1984. These tests will be funded primarily by the private sector with DOE providing up to 25 percent of costs in the form of facilities, services and direct funding.

Alternative Disposal Concepts

The FY 1985 budget request for alternative disposal concepts is $12 million. The efforts conducted in this area are done so under the Subseabed Disposal Program which is an international program under the Nuclear Energy Agency in which the U.S., the European Economic Community and seven other countries participate.

Subseabed disposal is the only alternative to mined repositories currently being studied by DOE. The primary mission of the subseabed disposal program is to assess feasibility of isolating radioactive waste within the stable sedimentary formations of the deep ocean floor. The FY 1985 subseabed program request will allow the Department to complete the technical, environmental and institutional feasibility studies by 1990.

The Subseabed Disposal Program is intended to coordinate our efforts with several other Federal agencies and international groups and to proceed toward the goal of determining overall technical and environmental feasibility of the concept. DOE will utilize the many laboratories, equipment and ships which were developed and operated by other agencies and international communities.

In FY 1985, the Alternative Disposal Concepts program activities on the subseabed concepts will include cooperation with other nations' seabed disposal program through the Nuclear Energy Agency of the Organization for Economic and Cooperative Development (NEA/OECD). DOE is participating in the International Seabed Working Group on a cooperative basis. Efforts will include environmental science studies, physical oceanographic and biology studies, sediment mechanical response studies and waste emplacement studies.

One of the major efforts in FY 1985 will include continuing the thermal program which includes the In-Situ Heat Transfer Experiment (ISHTE) to test capability of the subseabed to accept waste containers. This experiment is a critical path item for the completion of the subseabed feasibility assessment. It will allow completion of the measurement of in-situ sediment strength and heat transfer capability of the sediment through deployment by an international team. These measurements will be taken by U.S. and the international devices attached to the sea bottom platform. Also, in-situ measurements of hole closure following penetration of the sea floor through an international team effort will provide information critical to assessment of the containment capability of the sea floor.

The FY 1985 request also provides for the completion of the seafloor mapping of the Atlantic references sites, testing of in-situ hole closure using free-fall penetrometers, completion of the construction of the ISHTE test platform in FY 1985 for deployment in FY 1986, deployment and recovery of an ISHTE mock-up platform, completion of biological and ocean models for migration of radionuclides, and acquisition of field data on the major parameters necessary for the prediction of the degree of containment provided by the subseabed and the ocean.

Generic Methods and Supporting Studies

The FY 1985 budget request for generic R&D and supporting studies is $2.174 million.

The Generic Methods and Supporting Studies activities include three main areas of effort: international program support, special technical reviews, and waste management system studies. The thrust of these efforts is to assure adequate international cooperation, provide an independent assessment of the technical adequacy of the program, and evaluate potential alternatives which could improve the cost, schedule or technical aspects of the Civilian Radioactive Waste Research and Development programs.

During FY 1985, the Department's international program efforts will support bilateral and multilateral international agreeements. Summary reports will be prepared on the various international programs of the numerous countries emphasizing the status and planning of international waste management activities. At present there are agreements governing information exchange with six countries; they are: Canada, the United Kingdom, the Federal Republic of Germany, Sweden, Belgium and Japan. Discussion with four additional countries are expected to result in additional agreements.

In FY 1983 and FY 1984, a joint DOE/NRC Notice was published stating the U.S. intent to cooperate and provide technical assistance to non-nuclear weapons states in the field of spent fuel storage and sisposla. We have received expressions of interest from Egypt, Korea, the Netherlands and Brazil. Informal expressions of interest have also been expressed by other countries.

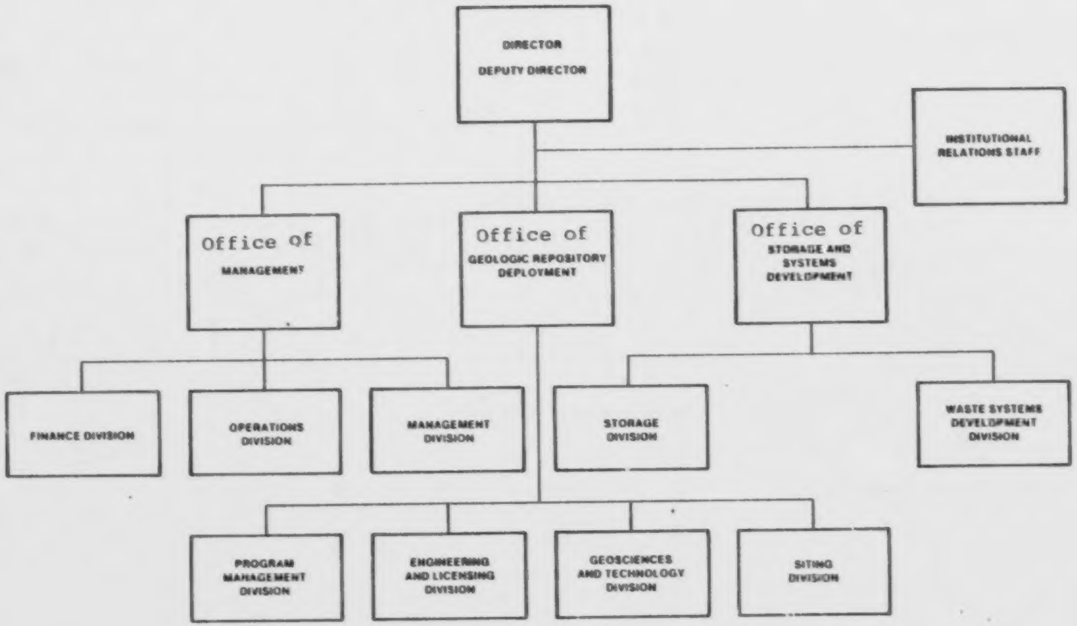
During FY 1985, support of special technical reviews by the National Academy of Science (NAS) assisted by the Department of Transportation, and the Bureau of Mines will continue for their evaluations of rock mechanics and tunneling techniques in support of waste management activities. Independent assessments of technical and programmatic issues related to the integration and conduct of the Waste Management and Fuel cycle activities will continue. DOE will also support nuclear fellowship and university programs in the waste management area.

Program Direction

The FY 1985 budget request to fund five FTE's essential to manage the Civilian Radioactive Waste Research and Development programs is $266,000. The personnel required are located at DOE Headquarters and include administrative and technical talent who manage a broad range of activities, which include research, development, demonstration, industrial involvement, international and university programs. Their responsibilities include assessment of the technical progress, milestone progress, cost expenditures, guidance, overview and integration of all the contractor's activities, and initiation of appropriate actions to resolve problems in any of the R&D areas.

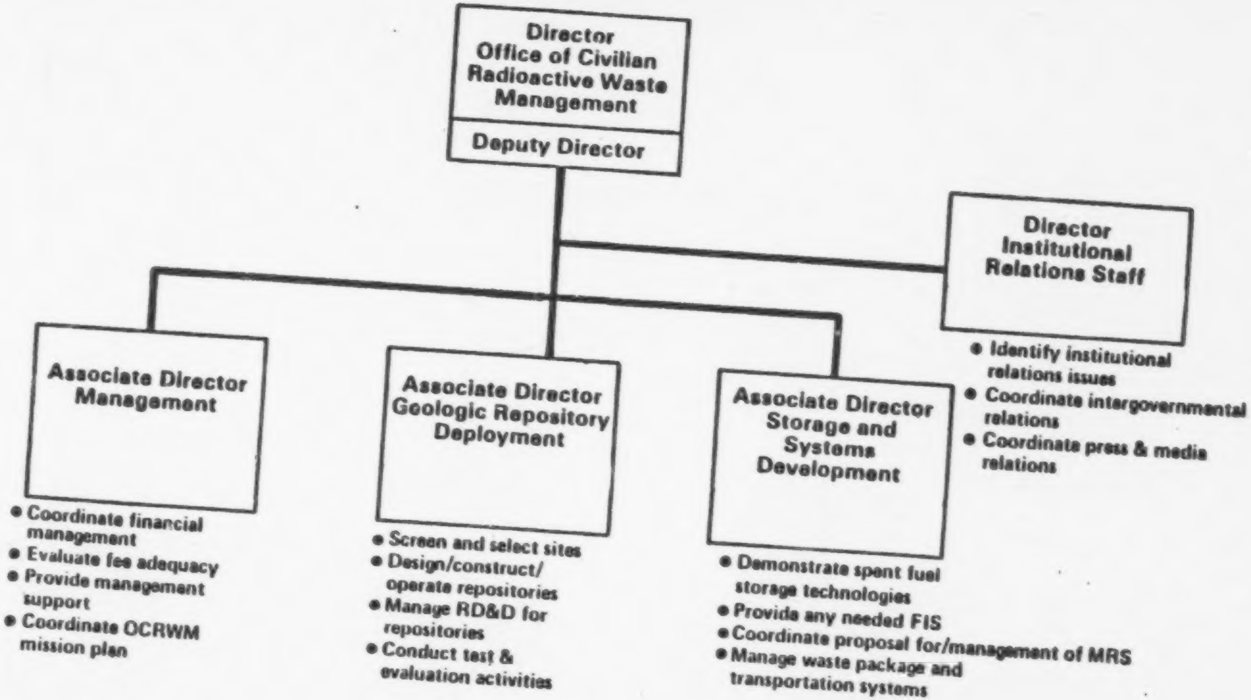
This concludes my remarks in support of the FY 1985 Nuclear Waste Fund Program and the Civilian Radioactive Waste Research and Development Program. I shall be pleased to answer your questions at this time.

DOE
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT


DIRECTOR
DEPUTY DIRECTOR
INSTITUTIONAL RELATIONS STAFF
Office of MANAGEMENT
Office of GEOLOGIC REPOSITORY DEPLOYMENT
Office of STORAGE AND SYSTEMS DEVELOPMENT
FINANCE DIVISION
OPERATIONS DIVISION
MANAGEMENT DIVISION
STORAGE DIVISION
WASTE SYSTEMS DEVELOPMENT DIVISION
PROGRAM MANAGEMENT DIVISION
ENGINEERING AND LICENSING DIVISION
GEOSCIENCES AND TECHNOLOGY DIVISION
SITING DIVISION

ATTACHMENT 1

Office of Civilian Radioactive Waste Management



Director
Office of Civilian Radioactive Waste Management

Deputy Director

Director
Institutional Relations Staff

- Identify institutional relations issues
- Coordinate intergovernmental relations
- Coordinate press & media relations

Associate Director
Management

- Coordinate financial management
- Evaluate fee adequacy
- Provide management support
- Coordinate OCRWM mission plan

Associate Director
Geologic Repository Deployment

- Screen and select sites
- Design/construct/operate repositories
- Manage RD&D for repositories
- Conduct test & evaluation activities

Associate Director
Storage and Systems Development

- Demonstrate spent fuel storage technologies
- Provide any needed FIS
- Coordinate proposal for/management of MRS
- Manage waste package and transportation systems

ATTACHMENT 2

Senator DOMENICI. Thank you very much, Mr. Lawrence.

Let me suggest to the Senators present that we have four public witnesses following Mr. Lawrence, and we are supposed to go to a joint session for the President of France at 3:10. I have indicated that I intend to go. Obviously, if we don't finish the witnesses, we could come back and do that. I would be disposed to do that also. I wonder if any Senator intends to stay through the President of France's speech and inquire, or do we all want to go?

I gather we're all going. All right. We will still try to work you all in in any event.

I have two quick questions. Obviously that was landmark legislation that we adopted in that lame-duck session. A number of the Senators on this committee were very much involved. We worked very hard on a number of parts of it. But let me just quickly ask you, that portion that had to do with the State participation, could you give us a brief status report on that program in terms of the interactions with the various States under the Nuclear Waste Act? How well is it working and, in your opinion, how well are these whole States receiving this process that we've recently put in statute law?

Mr. LAWRENCE. Well, sir, we do have extensive interactions with all of the States in both the first and second repository programs. This is assistance in the form of grants in which they monitor our activities and actually have people reviewing, at the expense of the fund, our programmatic activities.

On a bimonthly basis we have meetings with the State representatives at our Columbus office to go over the progress in the first repository program, and meetings, as necessary, with the 17 States that are under consideration for the second repository.

During the process of developing the siting guidelines, we had extensive interactions with those States that were concerned with that process.

In the course of coming up with 5 different drafts of the guidelines, and receiving over 3,000 comments, we had a total of 29 individual or collective meetings with the States to get their views and comments on those guidelines.

I'd say the interactions with the States are going about as well as can be expected. Obviously they are very concerned about the prospects of possibly having a nuclear waste repository sited within their State, but the cooperation in general is very good, and we think that the provisions of the act do provide a good sound basis for Federal-State interaction.

Senator DOMENICI. I assume that the Supreme Court decision, the *Chadha* case, does not have a constitutionally adverse impact on that concurrence part of the law?

Mr. LAWRENCE. Sir, it does not have a negative impact on any portion of the law, with the exception of the fee adequacy, where a one House veto would have been able to withhold a change in the fee. But we have stated to Congress that we would send the fee adequacy report, and any change in the fee would be submitted to the Congress as well.

Senator DOMENICI. All right. I have an additional question and I will submit that in writing.

Senator Johnston.

Senator JOHNSTON. Thank you, Mr. Chairman.

Mr. Chairman, under the Nuclear Waste Policy Act, you will recall we have a dual track. One track is supposed to be for geologic disposal, and the other is monitored, retrievable storage. The monitored, retrievable storage has certain goals and dates and descriptions.

This administration has chosen totally to ignore the MRS, while at the same time not proceeding on the time schedule with the geologic disposal.

One good indication of the fact that the MRS is being totally ignored is the fact that the utilities, through the then ratepayers or through their own money, however you want to call their collections, will be spending about $400 to $500 million per year for geologic disposal. On the other hand, the budget request for MRS is $8.5 million in fiscal year 1985, and it will be $1.5 million in fiscal year 1986 and $1.5 million in fiscal year 1987. Moreover, they have a conceptual design that I think does not qualify as an MRS, and which I think the public would never accept, and that's this proposal to have these little concrete containers which they're just going to put out in the sand in the desert as opposed to a constructed facility underground which would, I think, be necessary to obtain public support.

And what we're dealing here is public perception, to a very large extent. That's why you're not going to get a geologic repository approved by 1998. And, indeed, the administration itself, I think, realizes that, we're not going to make it by 1998. I don't know when, if ever, you're going to make it.

The Europeans, of course, have realized that. They have gone to monitored, retrievable storage.

Sometime, somebody in the administration is going to realize that and then the administration is going to try to get MRS built in a realistic way.

I think what we're seeing is the scene being set for accepting spent-fuel for storage at the reactor site in dry storage casks provided by the Federal Government. Now, in my view, it's not at all clear that this could be done under the act, it's not clear that it's feasible, it's not clear that the NRC would license it, and it's not clear the public would accept the transformation of each reactor site into a site for the storage of spent fuel for an indefinite period. I think we need to know a lot more about this plan.

I feel sort of out of breath every time we have one of these hearings. We say the same thing over and over again, and it doesn't produce any results. But just let the record reflect that when these dates roll around and nothing's been done and we don't have either a repository geologic or an MRS, just remember this Senator told you so and has been telling you so for a period of years. The administration won't do anything. Private industry, frankly, is not much help in this matter. I haven't seen any real support out of private industry for MRS. That's their privilege. But I'm telling you, geologic disposal is going to be a lot more difficult than you think it is. It's going to take a lot more time. It's already more difficult. The 1998 goal is not going to be achieved.

Well, I've said this before, I just didn't want the opportunity to go by without repeating it.

Mr. **Lawrence**. Senator, if I could respond very briefly to that.

Senator **Domenici**. Since he didn't have a question, what I was going to say is, do you have any comments on that?

Mr. **Lawrence**. Yes, sir. I'm sorry Senator Johnston feels that we're ignoring that. We have had discussions concerning this before. We certainly, in our opinion, are not ignoring this request at all. We are spending $25 million to submit the proposal to Congress to develop MRS as an option to geologic disposal.

That proposal will contain an implementation and funding plan necessary to have the MRS as a real viable option to the repository. The $1.5 million in 1986——

Senator **Johnston**. If I may interrupt.

Mr. **Lawrence**. Yes, sir.

Senator **Johnston**. You see, I'm not going to go into all the ways in which it doesn't meet the statutory plan. What we required was that was within a period of months that DOE would submit to the Congress plans which could be then funded and built. They're talking about an implementation plan and a funding plan. That's not even close to congressional intent.

Mr. **Lawrence**. Sir, all I can say is that in June of 1985, when the proposal is submitted, I am certain—it's our expectation and belief and hope that it will meet the full expectations of Congress.

Senator **Ford**. Everything's in 1985. It's a good year.

Senator **Domenici**. 1985 is a good year, you say? Well, it could be. It could be an excellent year. Who knows? Well, we're not there yet.

Is that all you have to say, Senator?

Senator **Ford**. Yes, sir; 1985 is a good year.

Senator **Domenici**. Bennett, do you have any more?

Senator **Johnston**. I have more. I won't say it here, I've said some of it before.

Senator **Domenici**. Good. Senator Evans, do you have anything?

Senator **Evans**. Everybody has had this in front of them so many times, and I guess I'm the only one that gets to ask some new questions they haven't heard before.

I'm concerned about the funding of the act and the projections you're making both on the cost and on the revenue side.

Have you had any reason to change the $20 billion total cost estimate, or is that a new one? Can you bring me up to date on the development, and currently how accurate you believe that total cost estimate is?

Mr. **Lawrence**. Yes, sir. Last summer we submitted a report to Congress which estimated the total cost of providing two geologic repositories and all the other studies and proposals provided for in the act, and estimated that a total cost into the next century is on the order of $20 billion.

We will be submitting another report to Congress this summer, determining the adequacy of the revenues to provide for the program costs. And it's our objective and expectation that our program can be operated within the funds provided by the 1 mill per kilowatthour.

Recent nuclear plant cancellations, and the delays have caused our near-term revenue projections to decline, but it's our belief that the program efficiencies and operations can be brought about which would make the 1 mill adequate to meet our program cost.

Senator **Evans**. I'd be curious to know what that projection is based on in terms of the plants you expect to be completed and operating and producing electricity, of the current ones —and I guess almost all of which are on hold or canceled, and new ones which have not yet started. What kind of a future are you looking toward in terms of the kind of revenue that will balance against a $20 billion expenditure?

Mr. **Lawrence**. Our projections had been based upon the Energy Information Administration's mid case for nuclear power generation. If I recall correctly, that was about 130 gigawatts of nuclear power installed out well into the next century. Obviously, that number may decline, and we would have to look at that and look at what the impact would be.

Those plants that are currently on order, under construction or completed, I believe we have a total of about 115 gigawatts of power. The two repositories provided for by the act would be more than adequate to provide the disposal capacity for that generation.

Senator **Evans**. You say plants currently on order?

Mr. **Lawrence**. Yes, sir.

Senator **Evans**. What does that include, all the ones that are half completed or——

Mr. **Lawrence**. I believe there are approximately 80 reactors operating right now. So that would be a balance on the order of 35 additional reactors. Those are the ones under construction or have construction authorization right now from NRC. So it's not just a gleam in a utility's eye, certainly. They're underway.

Senator **Evans**. It's more like a grain of sand in the utility's eye at the moment.

Do you know how many plants where construction has currently started are proceeding, and how many are either mothballed, canceled, put on hold, or stopped?

Mr. **Lawrence**. Sir, I'll have to provide that for the record. I don't have the answer to that right now.

[The information follows:]

COMMERCIAL NUCLEAR REACTORS

According to the latest information available as of March 22, 1984, there are 81 nuclear reactors fully licensed for commercial operation, four others licensed to load fuel and/or conduct low power testing, and 41 which have construction permits and which have definite schedules for completion. There are an additional seven units with construction permits which have been indefinitely deferred.

Of the 81 nuclear reactors licensed to operate, 76 are in commercial operation, two are near commerical operation and three are unscheduled for future operation. Those three are Three Mile Island 1 and 2 and Dresden 1.

Senator **Ford**. Dan, I think there's about 1,100 or 1,200 applications when I first came up here for generating facilities. It was a huge amount.

Mr. **Lawrence**. That's right. And it has gone down, and we have factored that into our revenue projections.

Senator **Ford**. So now it's down to what, 80?

Mr. **Lawrence**. Well, there are 80 operating right now, but we're still projecting another, I believe it's somewhere between 20 to 35 additional plants which will come online.

Senator **Ford**. So the prospects then and the prospects now have come close together. And it's three, California, Indiana, and Ohio, have all been terminated for various reasons.

Senator **Evans**. Well, it's a lot more than that.

Senator **Ford**. I'm just talking about the three worst ones on the list, they've been terminated.

Senator **Evans**. Well, you ought to include ours in the worst case, too.

Senator **Ford**. I'll let you speak for yours, I'll speak for mine.

Mr. **Lawrence**. Sir, there are 52 reactors on order right now.

Senator **Evans**. But of those where construction has started, how many are continuing?

Mr. **Lawrence**. I'd have to get that for the record, sir.

Senator **Evans**. It seems to me last year at least we asked the same question in developing the Pacific Northwest electric power plan, and the answer then was there are 20 under construction and 1 is continuing. Now, that may be different than our current circumstances, but there are lots of stops, cancellations and would-be stops.

Senator **Domenici**. So you will get that information for us?

Mr. **Lawrence**. We'll get that information for you, sir.

Senator **Evans**. Because I am concerned that we have some pretty good sense of what this is going to cost, because it leads to—you know, it leads to the determinations we're going to have to make on what is cost-effective relatively in the various sources of electric energy. We have got to include, and should include, I think, all of the direct environmental—I would consider this an environmental cost, just as increasingly we're going to have to consider the cost of acid rain protection, or whatever other environmental costs that are directly associated with coal-fired generation so that we can get a much more accurate picture on just what electric energy is costing from these different sources. And that's why I'm concerned and asked the questions regarding the one mill and whether that's really going to be sufficient or whether it's going to have to escalate rather substantially if we have fewer plants than we had once anticipated.

Mr. **Lawrence**. There are a number of factors that influence that, and that's one of the things our fee report to the Congress this summer will have to address.

Senator **Evans**. OK. I've got just one other question on indemnification. What is the current expectation if a particular location was selected as a national disposal site, what are the proposals for indemnification to the State or the community in which that's located for accident or damages either at the site or in transportation to the site?

Mr. **Lawrence**. Well, sir, we believe that will be covered by Price-Andersen, and have asked NRC to make it clear in their report to the Congress on Price-Andersen that the nuclear waste repositories and transport thereto are covered.

Beyond that, that does limit their coverage. The State of Washington has indicated they would like to have a different setup. We are prohibited under the Anti-Deficiency Act from signing a contract with open-ended coverage for liability for any accident, and any such liability would have to be approved by the Congress.

Senator EVANS. Do you believe that the current limits on Price-Andersen are sufficient to handle the potential problems?

Mr. LAWRENCE. I would certainly think that for any activity or any accident considered with a nuclear waste repository it would be more than sufficient, sir.

Senator EVANS. OK.

Senator DOMENICI. Thank you very much, Senator.

With reference to the auditing plan for the Nuclear Waste Program, we have had our staff begin discussions with the GAO on the possibility of some kind of quarterly reporting similar to that which we have in SPRO. I think a number of members feel that the programs that you presently are overseeing is so massive and the undertaking so difficult, with the tremendous amount of ratepayers' dollars at stake, and since that's the case, they think it's worth pursuing a more formalized system of accountability. I hope you will consider that, but maybe you could comment briefly on it.

Mr. LAWRENCE. Yes, sir. We do right now have an annual GAO report. The inspector general will review our program on an annual basis, and we're hiring an audit contractor, one of the big eight, to come in and audit our activities.

In addition to these formal auditing requirements, we are receptive to a proposal from EEI for a utility oversight committee to look at our activities. So certainly, sir, we're not suffering from a lack of interest or coverage of our program, but what you have suggested is something that we could take into consideration.

Senator DOMENICI. We surely don't want to load you up, but we had some pretty bad experiences with SPRO, it took a long time to get some things flushed out to everyone's advantage, and I hope that what we recommend is not put on top of the system, but rather that it works into the system that makes it more accountable periodically. You're talking about an awful lot of money and we want to be careful. It's not to hurt you, it's to really help you.

Wendell, did you have any questions?

Senator FORD. No.

Senator DOMENICI. All right. We're going to at least take Harold Agnew, who has come a long way. Would you please take the witness table, Dr. Agnew, and we're delighted to have you. Your statement will be made a part of the record. You may proceed.

STATEMENT OF DR. HAROLD M. AGNEW, PRESIDENT, GA TECHNOLOGIES, INC.

Dr. AGNEW. Thank you, Mr. Chairman. I'd also like permission to have part of the record this booklet, High Temperature Gas-Cooled Reactor HTGR Program, dated February 1984.

I noticed in the New York Times an article, and the lead paragraph said: several species of trees are growing more feebly than usual along the Appalachian's tallest peaks. From Camel's Hump in Vermont to Mount Mitchell in North Carolina, the trees are dead or dying. The cause of this massive disaster are not known for sure, but the circumstantial evidence is compelling. Only air pollution such as acid rain could damage forests over such a wide range.

It's the same thing that's happening in Germany. There may, in 10 years, be no more Black Forest. And this just emphasizes the need for nuclear energy, and to change the public's perception for the need for nuclear energy.

And I would like to submit that the HGGR Program, I believe, allows the opportunity to regain that public confidence which we have lost over the past years. It clearly is a more efficient system. It clearly is safer than the present system. Now, safety is something that many people in the industry are very upset about, but I think all of us would agree that the present jet airliners are much safer than the old fashioned propeller airplanes. That doesn't say the others weren't safe, but these are more safe.

And I think as far as the financial community is concerned, their ideas of investment's concerned, putting the investor's money on the line, they're very much in favor of having this type of technology available. The Gas-Cooler Reactor Associates have been working closely with us, Bechtel Engineering, Combustion Engineering, General Electric, United Engineers, Constructors, we're all working together to promote this technology.

It allows us to use uranium, not just for generating electricity, but also allows us to use the vast resources of the country for process heat which, again, will cut down on the acid rain.

Another point which is going to be, in my opinion, could be the asbestos litigation of the—complement of the asbestos litigation in the decades ahead, is the increasing level of radiation exposure workers are getting in light-water plants.

The facts show you the gas-cooled reactors in the United Kindom, and France and in the United States expose the workers to between 100 less, and 20 times less exposure than the water plants. And I think this is something that you as Members of the Congress and those of us in the industry have to face up to. And we can bring in new technology through the HGGR that will take care of this problem.

The size of the reactors, the present program, the integrated design covers everything from 400 megawatts to 1,200 megawatts electrical. As you mentioned earlier, there's some interest on the smaller type systems which would have some advantages in that essentially a single utility could completely control the reactor. It could be small enough so that it could be made in a factory. You would have excellent quality control. The labor force would be strictly understanding what they're doing. And I think we can bring this type of reactor out, which would have advantages to the United States for export, because it's a small size, around 100 megawatt electrical or 200 or so megawatts thermal which, again, would be ideal for process heat for large industries.

I think you're aware that the House counterpart of your committee has gone along with the President's initiative to support this program. They have suggested $47 million. We're suggesting that the total program should be around $52, with $2 million for capital equipment, and we suggest $4.5 million for reprocessing, and that matches the amount to the Federal Republic of Germany is also putting in this particular program.

Just for Senator Johnston's support, I would like to tell the Senator, if they would follow your recommendation on monitored retrievable storage, and put in Dr. Phil Hammond, who really understands the name of the game, we would get the show on the road.

For lack of time and in deference to the other witnesses, if you have any questions I'd be glad to answer them, otherwise, I'll cease now.

[The prepared statement of Dr. Agnew follows:]

STATEMENT SUBMITTED FOR THE RECORD

SUBCOMMITTEE ON ENERGY RESEARCH AND PRODUCTION

ENERGY AND NATURAL RESOURCES COMMITTEE

UNITED STATES SENATE

FY 1985 DOE AUTHORIZATION

HIGH-TEMPERATURE GAS-COOLED REACTOR PROGRAM

HAROLD M. AGNEW
PRESIDENT

GA TECHNOLOGIES INC.

March 22, 1984

Mr. Chairman:

I am Harold M. Agnew, President, GA Technologies Inc.

I appreciate your providing me this opportunity to testify before your Committee and to comment upon the High Temperature Gas-Cooled Reactor (HTGR) Program. Your Subcommittee specifically and the Congress at large has consistently supported continued research and development of the HTGR for many years and we believe that this has been a very prudent decision. We are especially gratified this year that the HTGR is an important part of the FY'85 Department of Energy nuclear fission budget request recently submitted to the Congress by the President.

Before proceeding with my presentation on the program and our specific recommendations for FY'85, I would like to acknowledge the contribution made to the HTGR program by the other participants. Although GA is the principal contractor to the DOE on the program, and has been the pioneer of HTGR technology in this country, the participation of these organizations has been vital to the continuing vitality of the program and to its prospects for success. First, I would mention Gas Cooled Reactor Associates (GCRA), the utility/user organization which provides to the program the current perspective and requirements of the ultimate user of HTGR systems and, in addition, performs for the Department of Energy the overall program coordination function. I would next mention General Electric, Combustion Engineering, United Engineers & Constructors and the Bechtel Group who bring into the program the broad experience and capability of their respective companies in the nuclear field. Finally, I would like to mention the National Laboratories and particularly the Oak Ridge National Laboratory who has been a key participant in the HTGR program since its inception and is responsible for a number of significant technical advances related to the HTGR.

My testimony today will cover the changing conditions and goals of the nuclear industry, how the HTGR can be adapted to meet those needs and the specific budget recommendations for the HTGR program and the associated thorium recycle program.

In reviewing the nuclear industry in the U.S. today, it is clear that there are a number of factors which contribute to its current depressed condition. Among these are the lack of confidence in current nuclear systems by significant segments of the public, the regulatory agencies, financial institutions, and other interested groups. If their confidence is not restored, it will be difficult, if not impossible, for the industry to rebound and the full benefits of nuclear energy to be realized. Consequently, we at GA find merit in the development and demonstration of a Modular High Temperature Gas Cooled Reactor. The HTGR system seems particularly well adapted to meeting these changed requirements.

It is also becoming apparent that a large segment of the utility industry has shifted their interest in nuclear to significantly smaller units than had been provided in the past. This shifting is related to both reduced forecasts of low growth and financial risk considerations. It is for these reasons that we at GA find merit in focusing the HTGR program to smaller systems and, in particular, to initiatives aimed at the development and demonstration of small, passively safe modular HTGRs. All HTGRs provide a high level of inherent safety from the use of inert helium as the coolant, a graphite reactor core and a ceramic fuel and fuel cladding which are stable to very high temperatures, and a very large thermal heat capacity which leads to slow thermal responses to postulated accidents.

The same features of the HTGR which contribute to nuclear safety also result in very low levels of radiation exposure to plant operating personnel. Although this has not been the focus of major attention to date, we believe that this is an area that will receive increasing attention in the future.

MODULAR HTGR PROGRAM

Studies of small (less than 300 MWt) modular HTGRs have received increased emphasis over the past several years with support derived both from GA and from the ongoing DOE supported national program. This work has benefitted extensively from the experience derived from operating HTGRs in the U.S. and the Federal Republic of Germany. The majority of this activity has been devoted to defining the characteristics of such systems and determining the effect of passive safety on plant simplicity, and the optimizing of the modular reactor for use in the generation of electricity or the co-generation of electricity and high temperature steam for use by the process industries. During the past year significant efforts have also been initiated by Bechtel to focus on overcoming the cost disadvantages normally associated with small nuclear systems by taking advantage of the simplicity and safety of the modular HTGR in the design and construction of the plant.

The results of these studies to date have been very positive although they have not, in all instances, progressed to the stage where definitive judgments can be made. The following paragraphs summarize several conclusions that can be made from the completed studies.

Passive Safety

As indicated above, the HTGR class of reactors characteristically provides a high level of inherent safety which leads to essentially zero fission product release during normal operation or postulated accidents. For small modular HTGRs, these features can be achieved with completely passive mechanisms.

The work done to date has shown that modular plants in sizes of up to at least several hundred MW(t) can be designed so that essentially zero release of fission products from the core under accident conditions without the utilization of active safety systems. This can be totally accomplished by passive conduction and/or radiation of the heat away from the reactor core in an effective manner such that the HTGR TRISO-coated fuel particles will not reach temperatures which would cause significant fission product release from the coated fuel particles. It also appears that these are demonstratable features. This transparent level of safety should restore confidence to the public and to the plant owner and operator who will be assured that his equity is protected. Further, assuming that the licensing authorities give full credit to this feature, this would allow simplification of the nuclear system, substantially reducing the requirements for nuclear grade equipment in the plant and allowing nuclear requirements to be localized - a key factor in reducing the balance-of-plant (and overall plant) costs.

Reduced Costs

Cost studies performed to date indicate that individual modular units can be expected to have substantially lower unit capital costs ($/kWe) than would be projected for "conventional" nuclear plants scaled down to the same size. This reduction results both from simplifications embodied in the design, the reduction in the number of safety related systems, localization of nuclear requirements, the saving inherent in an increased level of factory fabrication and from the shorter construction schedule. Additional reductions in unit cost would be expected to result from the deployment of multiple modules at a single site. Additional studies currently underway will provide a basis for assessing whether the reduced capital requirements and other benefits resulting from small HTGR systems are sufficient to result in the enthusiastic support of the utilities and the process industry.

Recommended Reference Small HTGR Concept

The major features of the reference concept are illustrated in Figure 1. The design is characterized by an integrated "in line" arrangement of all of the primary system components in a steel vessel. Key performance and design features are provided below:

Key Features of Reference Concept

Power level, MW(t)	250
Net power output, MW(e)	95
Power density, Watts/cc	4.1
Core type	Pebble Bed
System pressure, psia	1050
Core outlet temperature, F	1270
Core inlet temperature, F	688
Reactor vessel type	Steel
Steam generator type	4-helical bundle
Circulator type	4-horizontal mounted electric motor driven
Control type	Control and shut down rods in reflector
Refueling concept	Continuous, on line

Demonstrated features incorporated in the reference design include: Fort St. Vrain type steam generators; current pebble bed fuel technology; LWR pressure vessel technology; and operating system and fuel temperatures and pressure below those demonstrated by operation of the Peach Bottom 1, AVR and Fort St. Vrain reactors. Additional evaluation of design alternatives would be required to optimize the reference concept.

The ongoing modular activities have indicated a number of promising design alternatives. Of particular interest is the substitution of a prestressed concrete reactor vessel (PCRV) for the steel vessel to take advantage of the special features of that system.

Program Cost and Schedule

Based on the reference concept, GA has developed a first order cost estimate and schedule for a program leading to the operation of a prototype plant. Certain key assumptions are implicit in the information presented. First, the schedule for performance of the work would be adequately funded and the Nuclear Regulatory Commission would be in a position to evaluate the unique characteristics of the modular system and establish the licensing guidelines in a time frame consistent with the program goals. Second, the program would not be inhibited in the use of technologies developed outside of the U.S. Third, the program goals for the ISR prototype are well defined and stable and fourth, the program is organized to permit effective management.

The total cost for the design, development and construction of a 250 MW(t) prototype HTGR is estimated at $673 million (1983 dollars). The breakdown of costs is approximately $174 million for design, $132 million for development (and design verification) and $367 million for plant hardware and construction. In addition to the above, the cost of the initial core fabrication and uranium would be $20 million.

No estimate has been made as yet of the cost of operating the prototype plant during startup and test operations or during subsequent power operations. Similarly, no estimate has been made of offsetting revenues from the sale of steam or electricity or from revenues that might result from the sale of the plant by the government at its commercial value.

Assuming program authorization in FY 1986, it is estimated that this plant could achieve initial full power operation in FY 1993.

A key premise in achieving an early operational date and demonstrating the cost benefits associated with the modular system is the responsiveness from the Nuclear Regulatory Commission. This would require that the NRC be in a position to evaluate the unique characteristics of the modular system and establish the licensing guidelines in a time frame consistent with the program goals. Congressional guidance may be required to insure the level and timeliness of NRC participation. Further, to insure full benefit from the prototype project, the licensing approach should be structured to allow for NRC "type certification" of the modular design.

An important element of the recommended program is to subject the plant to a full series of tests to demonstrate its capability to remove the after-heat associated with accident conditions through passive mechanisms.

Program Organization and Structure

GA recognizes that the ultimate organization and structure for carrying forth a prototype Modular HTGR project will be made by the Government. A key participant in any such project, however, would be a lead nuclear system designer/vendor - a role which GA is singularly qualified to assume. As indicated earlier, not only is GA the pioneer and only historic vendor of HTGRs in the U.S., it is also the prime repository of the technology. In addition, GA is the 45% owner in HRB (55% owned by Brown Boveri & Cie, Germany) the designer and builder of the two HTGRs in Germany. Through this association, GA would be able to bring to the project those technologies demonstrated in Germany which would be incorporated in an optimized modular plant design. If selected for this role, GA would plan to establish an integrated nuclear system project team including Combustion Engineering and other current participants in the HTGR national program.

Applications

The ultimate utilization and market for the modular HTGR will depend upon successfully demonstrating the technical features of the system and achieving an acceptable level of economics relative to alternative systems. A standardized, licensable (certified) design would have wide applicability for the incremental addition of electric generation capacity, and for the cogeneration of steam and electricity for the process industries. If the full economic promise is achieved, the system may also be deployed as multiple modules to provide a lower risk approach to addition of large blocks of generating capacity. If separation of the safety related functions is achieved, the modular system could also be considered as a retrofit heat source for existing fossil generating units which cannot conform to updated standards for emissions or for which the current fuel has become non-economic. The modular plant sizing and its level of safety also provides an opportunity to export nuclear power to countries previously excluded from the benefits of nuclear resources by lack of a small inherently safe reactor system.

In the future, the operating experience and technology base derived from the steam cyclo plant will form a strong foundation for the deployment of higher temperature HTGRs adaptable to hydrocarbon reforming, coal gasification, and other advanced uses.

GA believes the Modular HTGR is a most promising concept and should receive increased emphasis in the FY'85 program with specific attention to refining the program requirements, economics and key areas of technology.

INTEGRATED HTGR

Our enthusiasm for a small Modular HTGR does not lessen our support for the multi-hundred megawatt HTGR program. The emphasis of the current HTGR program supported by the Department of Energy is the 2240 MW(t) HTGR which is of the so-called "Integrated" design. The Integrated HTGR design is typified by a configuration in which the reactor core and primary loops are integrated within a single prestressed concrete reactor vessel (PCRV). This design provides a high degree of inherent safety. A two-loop Integrated HTGR which uses the same mechanical components and fuel as the 2240 MW(t) HTGR, would have a thermal rating of 1170 MW(t) with a net electrical output of 440 MW(e). The major difference between the two-loop and four-loop designs is in the sizing of the system integrating PCRV.

The two-loop HTGR appears to be in the size range of interest for concentrated industrial cogeneration applications while retaining flexibility through the addition of power loops to meet the future demand of the utilities for major additions of base load electric power production.

The assessments performed to date on the Integrated design HTGR indicate that the probability of a significant fission product release from the plant is well below that for other current reactor systems and many orders of magnitude below the interim NRC safety goals.

The major design changes incorporated in the Integrated HTGR from Fort St. Vrain have been made with the specific objectives of improving reliability and maintainability. These changes include the multi-cavity PCRV, a simplified motor driven helium circulator, the elimination of the reheat cycle, the lowering of the primary system operating temperatures and a reduction in power density. Also included in the design is the use of in-situ refueling which simplifies and speeds up the fuel replacement operations. Additional design improvements on the HTGR are anticipated from activities currently underway which will result in increased levels of inherent safety and reduced costs. These activities will include a review of the features of the 500 MW(e) plant (HTR-500) being designed in Germany by HRB, which has as its goal reaching competitive energy costs with 1300 MW(e) PWRs.

GA believes the Integrated HTGR should continue to receive support through the Department of Energy with the emphasis shifted to the two loop 1170 MW(t) version and modification to that design to accommodate higher levels of inherent safety and changing user requirements.

On March 14, 1984, The House Science & Technology Committee authorized $47M for the HTGR Program in their FY '85 DOE Authorization bill. We appreciate the Science Committee's increase in FY '85 funding and support their effort to encourage the Department of Energy to research and develop advanced reactor concepts.

However, GA Technologies recommends that $52 million (including $2 million for capital equipment) be authorized in the FY'85 Department of Energy Authorization for the HTGR Program. This budget level would permit: continuation of the effort on the Integrated HTGR design; an increased effort on the Modular HTGR and substantial progress toward resolving the open questions of this concept; a continuation of a redirected technology program supportive of both the Integrated and Modular design efforts; and sustaining an effort on advanced, higher temperature versions of the HTGR systems.

Thorium Recycle

The Thorium Recycle Program, under the direction of the Oak Ridge National Laboratory, is a critical part of the National HTGR program which has been supported and funded by your Committee for many years. The House Science Committee has authorized $3M to continue this program. We, however, recommend your Subcommittee authorize $4.5 million to continue work in the following HTGR fuel recycle areas: storage of HTGR spent fuel; development of designs and economics for rail and truck shipping of spent HTGR fuel; development and testing of volume reduction methods; and development of packaging and disposal forms. This work would cover both the prismatic and hexagonal fuel element configurations.

The U.S./Federal Republic of Germany cooperative spent fuel treatment program has provided an excellent example of a modestly funded program in both nations with major accomplishments. In FY'85, the FRG plans to spend roughly an equivalent amount to the $4.5M requested in our testimony.

In summary, GA Technologies recommends your Subcommittee authorize $52 million (including $2 million for capital equipment) for the HTGR Program and $4.5M for the Thorium Recycle Program.

I would request that the brochure entitled, "HTGR Program, February 1984" be made a part of the record of these proceedings.

Finally, thank you again for the opportunity to present GA's views before your Subcommittee.

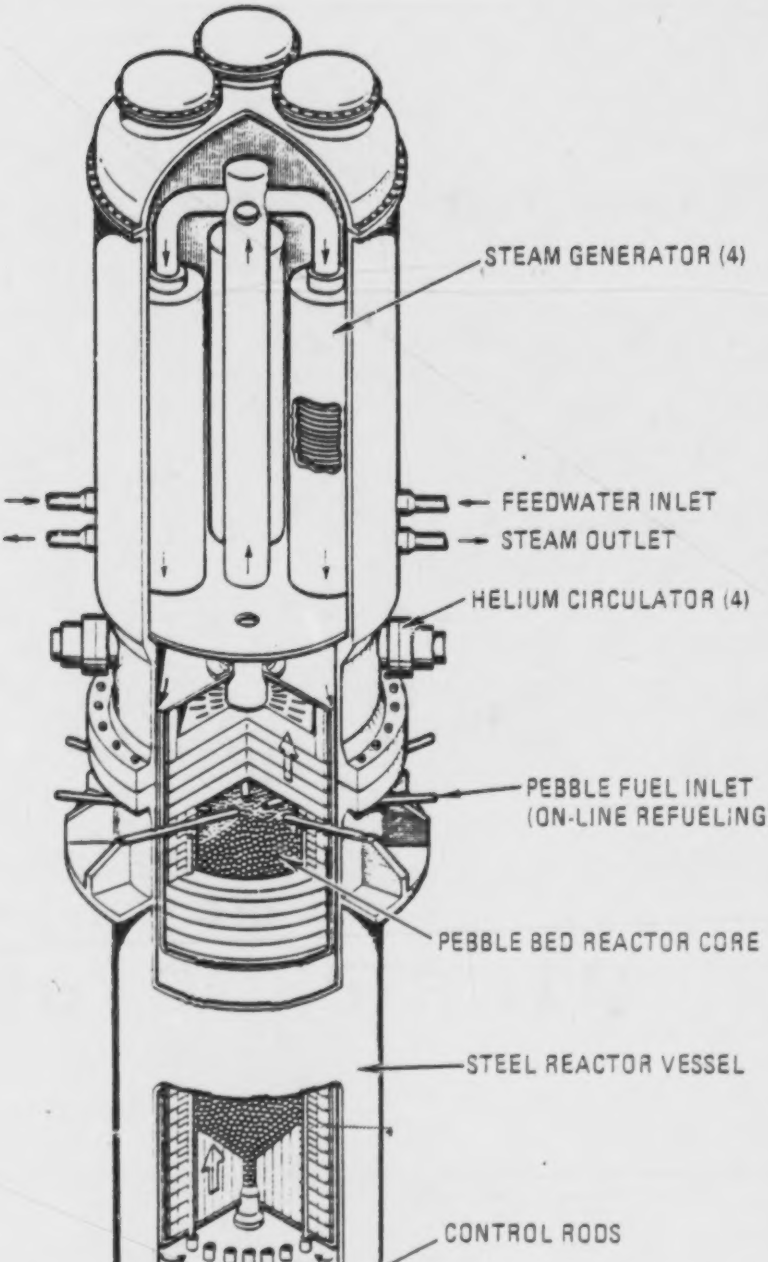
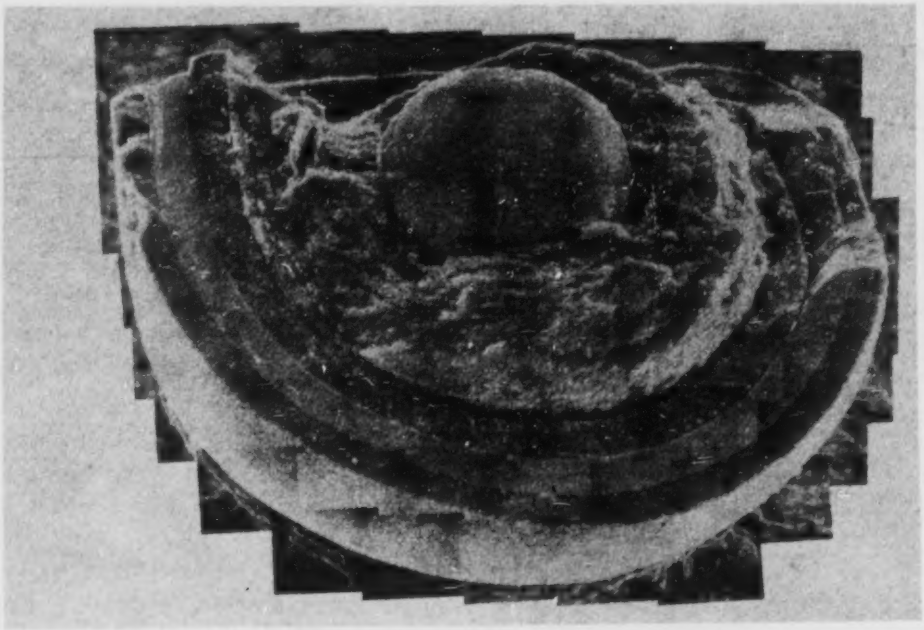

STEAM GENERATOR (4)
FEEDWATER INLET
STEAM OUTLET
HELIUM CIRCULATOR (4)
PEBBLE FUEL INLET (ON-LINE REFUELING)
PEBBLE BED REACTOR CORE
STEEL REACTOR VESSEL
CONTROL RODS
PEBBLE FUEL DISCHARGE

Fig. 1 100-MW(e) modular HTGR



HIGH TEMPERATURE
GAS-COOLED REACTOR
HTGR PROGRAM

FEBRUARY 1984

BRIEFING
DOCUMENT ON

HIGH TEMPERATURE GAS-COOLED REACTOR

HTGR PROGRAM

PREPARED BY
GA TECHNOLOGIES INC.

FEBRUARY 1984

Preface

This document has been prepared by GA Technologies to provide background information on the High-Temperature Gas-Cooled Reactor (HTGR) program that will be useful in deliberations on the FY-85 nuclear budget. The HTGR program has maintained strong user support during a period of nuclear power uncertainty because of the unique role it can fulfill in the national energy picture. The HTGR can contribute as a source of electricity and as a supplement or replacement for fossil fuels for high temperature energy for industry. In addition, the HTGR possesses characteristics which provide a higher level of inherent safety than the current generation of nuclear reactors – one that provides maximum protection of public and plant investment, reduces radiation exposure for operating personnel, and minimizes environmental impact.

During the past few years the DOE/industry program has continued to make significant progress in establishing the design and technological foundation for an HTGR cogeneration plant. Technological compatibility and environmental and economic benefits for a number of cogeneration applications have been well defined. Studies of the small modular HTGR concept have received increased attention primarily because of the reactor's simple design, increased level of factory fabrication, and passive safety features (i.e., the ability to retain essentially all fission products under accident conditions without relying on any active safety systems). During this same period, the HTGR has also become a leading candidate to meet the defense program need for a new production reactor.

The program participants (including the utility, process, and supplier industries) strongly urge the Congress to continue government support for the HTGR program in order to insure the availability of this unique option.

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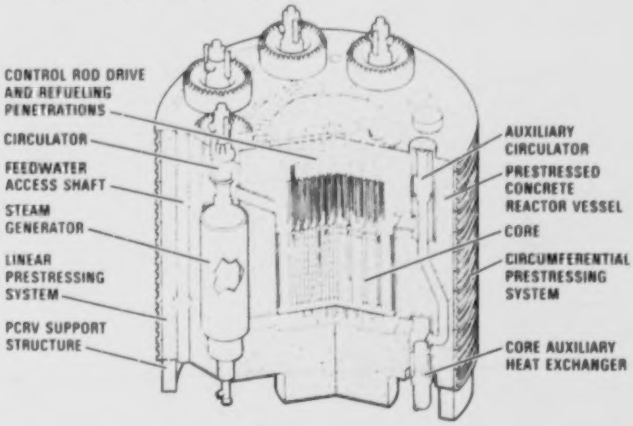
Integrated HTGR

Steam Cycle Reactors

In HTGR systems, helium gas is used as the coolant to remove the heat from the core. In the HTGR-steam electric/ cogeneration system the helium is heated to about 1266°F. This heat is transferred in a steam generator to produce steam for process use and/or electricity production. The entire primary system including steam generators, helium circulators, and auxiliary heat exchangers is housed within the thick-walled prestressed concrete reactor vessel. The fuel is contained in hexagonal graphite blocks, several thousand of which are stacked to make up the reactor core. Because of the systems high temperature capability, superheated steam can be produced, contributing to the thermal efficiency of about 40%, which is highest of any nuclear plant. By varying the numbers of loops, the integrated HTGR system is available in three sizes to match differing user needs, namely a 2-loop 1170 MW (t) /430 MW (e) plant, a 4-loop 2240 MW (t) /860 MW (e) plant, and a 6-loop 3360 MW (t) / 1300 MW (e) plant.

Cogeneration Applications

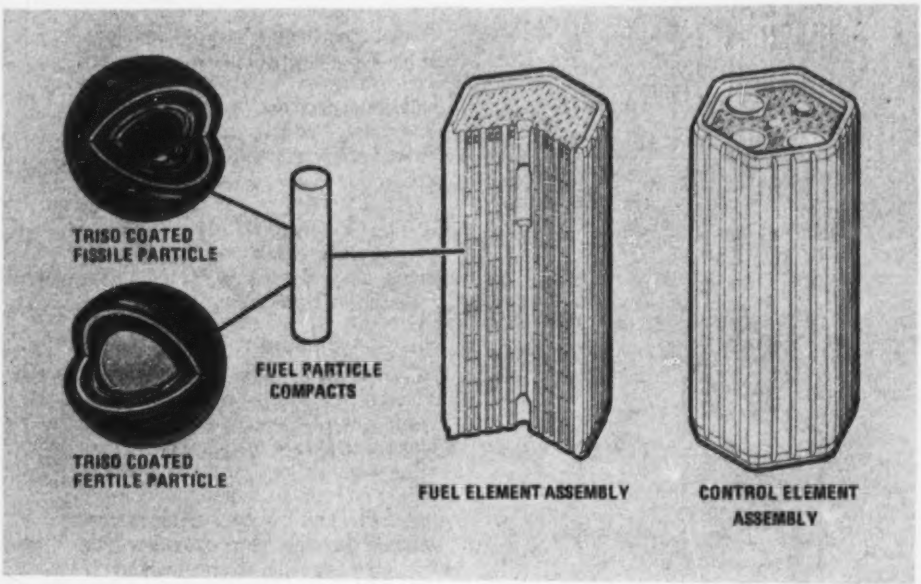
The steam cycle HTGR has the unique capability for providing high temperature (1000°F) process steam to meet industry needs while cogenerating electricity. A cogenerating HTGR can supply steam and/or electric power for a variety of industrial and other processes, including the recovery of heavy oil and tar sands, shale oil retorting, petroleum refining, and petrochemical and metals processing. In these cogeneration applications, the HTGR can displace fossil fuel usage and reduce the environmental impact of fossil combustion. The overall energy utilization in a cogenerating HTGR application typically approaches 90%.


CONTROL ROD DRIVE AND REFUELING PENETRATIONS
CIRCULATOR
FEEDWATER ACCESS SHAFT
STEAM GENERATOR
LINEAR PRESTRESSING SYSTEM
PCRV SUPPORT STRUCTURE
AUXILIARY CIRCULATOR
PRESTRESSED CONCRETE REACTOR VESSEL
CORE
CIRCUMFERENTIAL PRESTRESSING SYSTEM
CORE AUXILIARY HEAT EXCHANGER

HTGR Prismatic Fuel

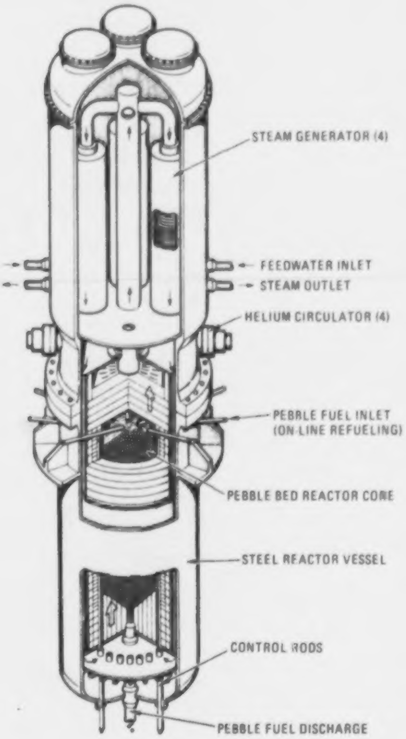
HTGR fuel is made up of tiny microspheres of uranium and/or thorium oxides, or carbides; each of which is coated with a TRISO coating (pyrocarbon and silicon carbide) to retain fission products. These particles, which are approximately 800 microns in diameter, are mixed with a graphite binder and formed into small compacts (about 1/2 in. dia. × 2-1/4 in. long). The compacts are sealed into fuel cavities running vertically through 31 in. high hexagonal graphite fuel elements. The active core consists of stacks of these graphite fuel elements through which the helium coolant flows in vertical channels.

The flexible uranium/thorium fuel cycle of the HTGR can use either a low or high enriched uranium cycle. It extends the yellow cake (U_3O_8) resource base of the nation by utilizing 25%–30% less uranium than a LWR, depending on the fuel cycle mode. HTGR fuel cycle costs are competitive in the stowaway mode, with cost benefits increasing with recycle and increasing U_3O_8 costs.


TRISO COATED FISSILE PARTICLE
TRISO COATED FERTILE PARTICLE
FUEL PARTICLE COMPACTS
FUEL ELEMENT ASSEMBLY
CONTROL ELEMENT ASSEMBLY

Modular HTGR

Modular HTGRs have received increased emphasis over the past few years because of their passive safety and simplicity of design. Both a lower temperature steam cycle design capable of producing electric power and/or process steam and an advanced higher temperature design, which may eventually be used for process heat applications have been studied.



Modular Steam Cycle

The design of the modular HTGR is characterized by an "in-line" arrangement of all primary system components in a steel pressure vessel, with the helium coolant flowing up through the pebble-bed core to the steam generators. The arrangement provides natural circulation shutdown cooling of the core under most circumstances. The passive safety of the modular HTGR results from the selection of a core thermal rating [less than 400 MW (t)] and power density which limit the fuel temperature even during a depressurized core heatup to below the damage threshold. During postulated accident conditions, sufficient decay heat can be dissipated indefinitely from the core by totally passive conduction and/or radiation to the environment to insure essentially zero release of fission products from the coated fuel particles.

A single-cavity prestressed concrete pressure vessel and prismatic fuel elements are also being evaluated for the modular HTGR design.

The modular HTGR is limited in output by the constraints on core volume attendant with passive cooling. The acceptability of the economics of these small systems are therefore dependent upon cost savings resulting from increased levels of factory fabrication, assembly, and testing; shortened construction schedules; localization of nuclear requirements to the reactor primary system components; and higher plant availability and capacity factors.

Key Performance and Design Features

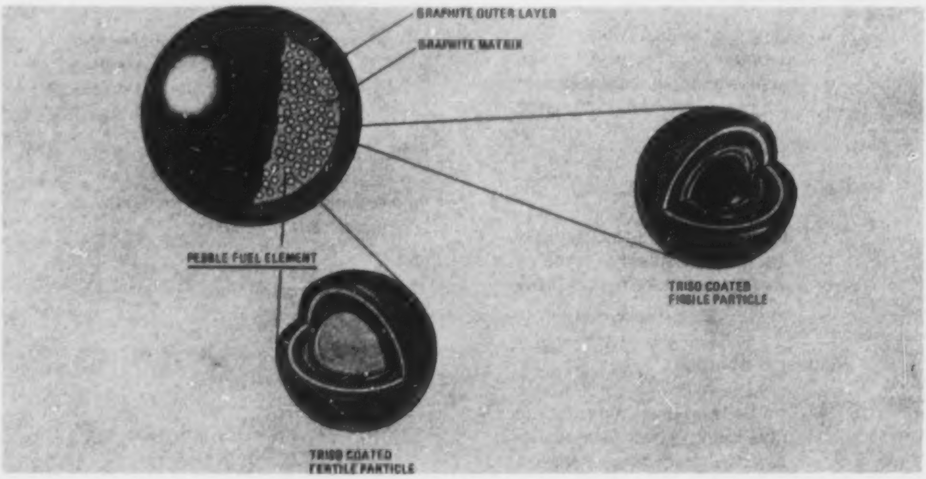
Power level, MW (t)	250
Net power output, MW (e)	95
Power density, Watts/cc	4
Core type	Pebble bed (320,000 balls, 60 mm diameter)
Fuel cycle	LEU/Th, recirculation
Decay heat removal	Passive system
Helium flow configuration	Upflow
System pressure, psia	1000
Core outlet temperature, °F	1270
Core inlet temperature, °F	688
Reactor vessel type	Steel
Steam generator type	4-Helical bundle
Circulator type	4-Horizontal mounted, electric motor driven
Control type	Control and shutdown rods in reflector, bottom mounted
Refueling concept	Continuous, on-line

Pebble Bed Fuel

The pebble bed reactor core consists of fuel elements approximately 2-3/8 inches in diameter which are loaded into the reactor and removed with the reactor on-line. Each element consists of TRISO coated fissile and fertile particles embedded in a graphite matrix contained within a graphite outer shell.

Advanced Process Heat

In the more advanced version of the small modular HTGR for higher temperature process heat applications, an integral steam generator/reformer replaces the steam generators in the upper section of the reactor vessel. With a reformer the modular HTGR, like the integrated HTGR, can be used to react steam and methane to form hydrogen and carbon monoxide, a reducing gas that can be integrated into such processes as oil shale retorting, coal liquefaction, and coal gasification to produce transportation liquids, ammonia, or synthetic pipeline gas.



HTGR Safety

Inherent Properties

The high safety level of all HTGRs results from inherent physical and nuclear properties.

Helium Coolant

- Chemically and neutronically inert
- Single phase under all conditions, no void formation
- Low heat capacity and low stored energy

Graphite Moderator/Core Structure

- Low power density and high heat capacity of massive graphite core ensures slow temperature response
- Graphite fuel elements and core support structure retain structural integrity to extremely high temperatures, providing large temperature margins

Ceramic Fuel

- Refractory coated fuel particles act as small spherical pressure vessels to retain fission products

Nuclear Properties

- Large negative temperature coefficient of fuel provides inherent shutdown mechanism

Special Features

The HTGR can incorporate other supplemental safety features, most of which are included in the integrated HTGR design, but which will probably be unnecessary with the modular HTGR.

Prestressed Concrete Reactor Vessel (PCRV)

- Integral containment of entire primary system
- Concrete vessel and liner maintained in state of compression by redundant, high strength, prestressed tendons
- Tendons can be inspected, tested and replaced
- Catastrophic failure of PCRV and rapid release of energy is incredible
- Combined pressure vessel and biological shielding, resulting in extremely low radiation exposure doses in containment

Engineered Safeguards

Inherent features are supplemented with engineered safety systems

- Independent, dedicated and redundant core auxiliary systems
- Reserve emergency reactivity shutdown system
- Reactor containment or confinement building

Integrated HTGR Safety

The integrated design incorporates all the inherent physical and nuclear features of the HTGR, including helium coolant, graphite moderator/core structure and ceramic coated fuel particles. In addition, the entire primary system is enclosed in a prestressed concrete pressure vessel (PCRV) . These features are supplemented by such engineered safeguards as three independent core auxiliary cooling systems, a reserve backup reactor shutdown system, and a containment building around the reactor.

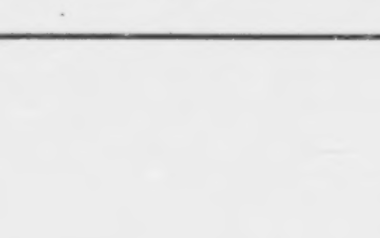
Time to Respond

The integrated design results in ample time to respond to loss of forced cooling or depressurization event

- Hours instead of minutes before damage to fuel
- No fast acting shutdown system is required

Compliance with NRC Goals

The consequences of severe HTGR accidents (core heatup due to loss of forced cooling and/or depressurization) are several orders of magnitude less than proposed NRC goals.



Modular HTGR Safety

Passive safety is a paramount goal for the modular HTGR. This means that the ultimate safety is a result of demonstratable natural workings of the system, rather than through engineered safety features. For the potentially most damaging postulated accident, namely a depressurized core heatup event where no active heat removal system is available and where natural circulation of helium within the reactor vessel is not available, decay heat is removed by radial conduction in the core and by radiation to peripheral systems and structures.

The power rating and power density of the ceramic core is selected to limit the maximum fuel temperature in such an accident to 1600°C. As a result, there would be no significant fuel damage, no significant fission product release, no impact on the health and safety of the public. The plant could normally be restarted and brought back to operation after such an event.

Inherent Safety

- Essentially zero fission product release during normal operation or any core heatup events
- No forced circulation auxiliary core cooling system required
- Inherent safety with natural circulation shutdown cooling system, or passive conduction and radiation
- Unparalleled level of protection to the public and plant investment

HTGR Environmental Features

HTGR provides higher levels of operational and environmental compatibility

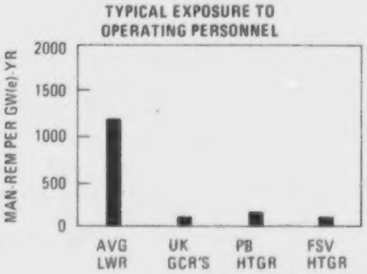
- Inherent safety results in maximum protection of public and plant investment, a basis for improved public acceptance
- Reduced cooling water requirements due to high thermal efficiency
- Improved siting flexibility
- Requires less uranium

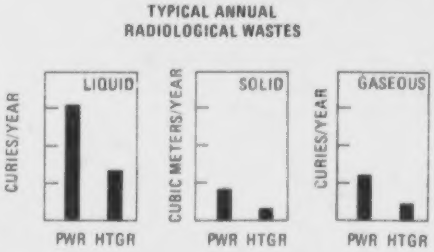
Reduced radioactivity wastes

- Helium cooled HTGR plants inherently release into the plant process streams substantially less radioactivity than an LWR

Significantly reduced operator exposure

- Experience at Peach Bottom 1, Fort St. Vrain, and Gas-Cooled Reactors in the U.K. indicate that radiation exposures to operating and maintenance personnel will be about 1/100 of those for an LWR


TYPICAL EXPOSURE TO OPERATING PERSONNEL


TYPICAL ANNUAL RADIOLOGICAL WASTES

Utility and Industry Support

Electric Utility Support Thru GCRA

- In 1978 a utility organization, Gas-Cooled Reactor Associates (GCRA), was formed to provide support and guidance to the HTGR program. GCRA utilities currently represent over 30% of installed electric generating capacity in the United States.

Industrial User Support

- In 1979 a group of major industrial firms formed a process heat users group to support continued development of the HTGR. Most of these companies merged into a Process Heat Advisory Committee established by GCRA in 1981. This committee, includes industrial firms in such energy-intensive industries as petroleum refining, chemicals, and metals.

HTGR Utility/User Conference

- In September 1983, GCRA sponsored its fifth international annual HTGR utility/user conference, which was attended by approximately 200 representatives of industry, government, and utilities from 75 organizations and nine countries.

Special HTGR Applications

Multipurpose Energy Roles

HTGR has the unique capability for providing high temperature process steam or heat in cogeneration applications

- Steam cycle HTGR can produce 1000°F steam to meet industrial process needs while cogenerating electric power
- Future higher temperature HTGR process heat systems open additional industrial and synfuel applications for use of clean, non-polluting nuclear process heat
- Can contribute to all major energy demand sectors of the economy

Technically Compatible

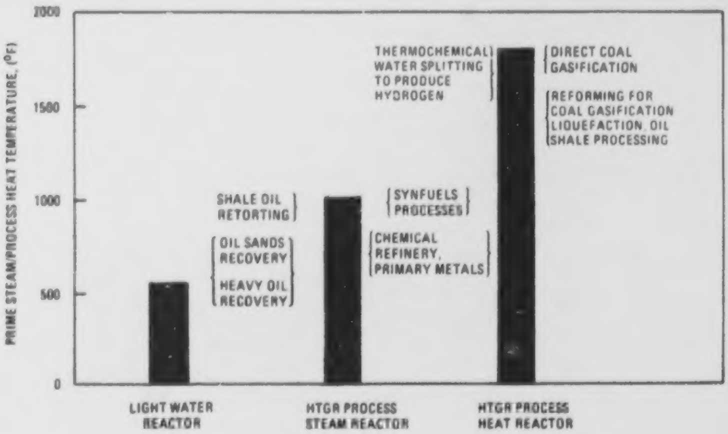
- Application studies show that steam cycle HTGR cogeneration plants are well suited to meet most process steam and electric power requirements

Reduced Energy Costs And Environmental Effects

- For most applications, the integrated HTGR cogeneration systems show energy costs reduced by 15% to 40%, when compared to coal-fired alternates. For modular HTGRs the costs are expected to be competitive
- Emissions to the atmosphere (such as SO_2, NO_x, CO_2), and particulates lowered by 40% to 100%, when compared with coal-fired alternatives

Increased Energy Utilization

- Overall energy utilization increased from 40% for electric power generation only to over 90% with nuclear cogeneration, with significant conservation of fossil fuel energy resources



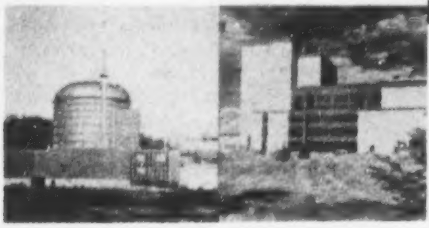
Technology Background

United States Program

Substantial experience technology, and test and manufacturing facilities currently exist in the U.S. and support the HTGR program.

Peach Bottom Unit 1 (40 MWe)

Peach Bottom Unit 1 HTGR was operated successfully by Philadelphia Electric Company from 1967 to 1974, when the plant was shut down for decommissioning after completing the planned demonstration program.



Fort St. Vrain (330 MWe)

- Has operated at full power with over 38.5% thermal efficiency
- Has generated over 3.8 billion kW hrs of net electrical energy to date
- Fuel performance excellent. activity in helium coolant less than 2% of design limit
- Virtually unlimited personnel access into reactor building
- Two segments of discharged fuel shipped to HTGR dry storage facility at INEL.
- Formal experience carryover program provides significant input for improving design of future HTGRs

Test and Manufacturing Facilities

- HTGR test facility compound, including air flow test facility, component test tower, PCRV models, tendon test facility, PCRV wirewinding machine, and helium circulator test facility
- Facilities available for manufacture of HTGR fuel

U.S. Program Funding Through 1983

Funds expended on the HTGR program through 1983, including the construction of the Peach Bottom No. 1 and Fort St. Vrain plants, amount to $1.6 billion dollars. Of this total, $600 million (or 37%) has been supplied by the government and $1.0 billion (or 63%) has come from industry.

International Program

Substantial international experience on gas-cooled reactor technology supports the U.S. HTGR program.

Germany

- AVR – 15 MW (e) HTGR with pebble bed fuel has generated 1.3 million MW hrs since 1967
- THTR-300 MW (e) HTGR with pebble bed fuel – initial criticality achieved in September 1983, rise to power scheduled for late 1984
- HTR 500 – follow-on project based on THTR experience in preparation for utility/user group
- Module – small HTR under study for industrial and process heat applications

United Kingdom

- Over 585 reactor years of operating experience with gas-cooled reactors
- DRAGON – first HTGR, operated from 1964-1975
- Units 1 of Hartlepool, Heysham 1 and Dungeness B AGR stations with multi-cavity PCRV's began operation during 1983, Units 2 will go on line in 1984

France

- Over 130 reactor years of gas-cooled reactor operating experience
- Carmen II and Comedie facilities – thermal barrier and core-flow tests conducted; capability for HTGR steam generator boiling stability, hot duct, and fission product release tests.

Japan

- Multi-purpose very high-temperature gas-cooled reactor (VHTR) under development since 1969
- Operation of 50 MW (t) experimental VHTR scheduled for 1990
- Hendel 10 MW helium test loop facility operating since 1982
- Growing cooperation with U.S. on HTGR

Technical Exchange Agreements

Relevant gas-cooled reactor experience is available through government and industry exchange and licensing agreements, and thru GA Technologies 45% equity participation in HRB (the German HTGR company).

International HTGR Funding Through 1983

International funds expended on the HTGR program through 1983 total $2.65 billion, consisting of $2.1 billion spent in Germany (including the AVR and THTR reactors), $300 million in Japan, and $250 million in other European countries.

HTGR Program

The government/industry HTGR program is focused on the development of the HTGR steam cycle/cogeneration system with complementary activities on higher temperature concepts for process heat applications.

GA Technologies is the lead industrial firm involved in the program. However, other experienced industrial companies are also directly involved in key areas, including:

- Bechtel Group
- Combustion Engineering
- General Electric
- United Engineers & Constructors

Program activities are also conducted at several National Laboratories

Gas-Cooled Reactor Associates (GCRA), represents the utility/user interests in the program, and performs an overall program coordination activity for the government.

Integrated Plant Program

The major fraction of the HTGR program activities has been directed toward the design, technology development and design support activities for integrated HTGR concepts in the size range from approximately 430 MW (e) to as high as 1300 MW (e).

The objective of the integrated plant program include:

- Demonstration of full scale HTGR systems and components including features incorporating technology evolution and Fort St. Vrain operational experience
- Establishing the licensing criteria for HTGR systems
- Confirming incentives of the HTGR nuclear systems
- Establishing the basis for a broad HTGR industrial infrastructure

Modular Plant Program

Interest in smaller nuclear power plants has resulted in a gradually increasing program effort in modular HTGR concepts which exhibit passive safety and factory fabricability coupled with shorter construction schedules and less investment risk. Individual plant sizes of the order of 100 MW (e) are being considered with the possibility of installing up to four such modular plants on a single site.

The focus of the small, modular plant program is on establishing design features which meet the criteria of passive safety and investment risk enhancement while still being commercially competitive with coal plants.

Other Program Activities

In addition the program includes:

- Conceptual design of higher-temperature versions of the HTGR
- Investigation of waste treatment, volume reduction and spent fuel storage for the HTGR fuel cycle
- Development of safety/licensing criteria, and review of long-range safety research plans
- International cooperation

FY-83 HTGR Program Accomplishments

Integrated Plant Design

- Completed conceptual design phase of 2240 MW (t) plant design
- Issued baseline documents for design based on plant, system, subsystem, and component level structure
- Initiated incorporation of integrated design approach to design and documentation activities
- Established licensing plan for standard nuclear island
- Design responsibility for steam generators transferred to CE
- Initiated effort on overall plant simulation code development
- Continued activities directed toward establishing a lead project

Modular Plant Design

- Completed preconceptual design studies indicating potential of passive safety

Technology Development

- Demonstrated the operating characteristics of developmental fuel coater unit
- Completed structural test series on models of flanged fuel elements indicating strength increase over previous design
- Completed hot cell examination of Fort St. Vrain fuel elements
- Completed plant seismic computer code development
- Completed 500-hr acoustic vibration test of full size thermal barrier panels
- Completed natural frequency vibration testing of steam generator helical coil
- Demonstrated weldability and formability of advanced alloys

Spent Fuel Treatment

- Identified options for handling spent fuel from HTGRs with LEU/Th fuel cycle
- Demonstrated in pilot plant burning techniques for reducing fuel volume

NRC Licensing Activities

- Completed reports on HTGR safety criteria for NRC review
- Completed source term study for HTGR

FY-83 NATIONAL PROGRAM FUNDING:

FOR HTGR DESIGN AND TECHNOLOGY	*$36 MILLION*
FOR SPENT FUEL TREATMENT PROGRAM	*$ 3 MILLION*
FOR NRC SAFETY/LICENSING ACTIVITIES	*$ 4 MILLION*

FY-84 HTGR Program

Integrated Plant Design

- Complete summary design and technology networks for 2240 MW (e) project
- Initiate preliminary design and associated documentation
- Complete incorporation of the integrated approach for plant design and licensing activities
- Evaluate improvement to constructability of steam generator
- Continue activities directed toward establishing a lead project

Modular Plant Design

- Complete preliminary evaluation of pebble bed design of modular reactors for electricity and process heat applications
- Complete preliminary evaluation of separability between conventional and nuclear site activities and related cost reductions
- Initiate trade studies to determine optimal features for passive safety
- Establish advanced systems design and technology development requirements, cost, and schedule

Technology Development

- Issue TRISO coated particle survival correlations under high temperature accident conditions
- Complete cross-flow tests on interconnected flanged fuel elements
- Complete steady state tests of full size main circulator bearing and seal assembly
- Complete a seismic test on full-scale section of steam generator helical bundle
- Demonstrate long-term thermal stability of advanced alloys at 850° and 950°C
- Characterize microstructural characteristics of advanced alloys after long-term thermal aging

Spent Fuel Treatment

- Establish criteria and designs for reducing the volume of HTGR spent fuel for economies in transport, storage, and disposal
- Deliver Fort St. Vrain spent fuel to Germany for process testing

NRC Licensing Activities

- Interact with NRC safety criteria and safety research program

FY-84 NATIONAL PROGRAM FUNDING

FOR HTGR DESIGN AND TECHNOLOGY	*$30 MILLION*
FOR SPENT FUEL TREATMENT PROGRAM	*$ 3 MILLION*
FOR NRC SAFETY/LICENSING ACTIVITES	*$ 2 MILLION*

Recommended FY-85 HTGR Program

Integrated Plant Design

- Complete reference documentation for the 2240 MW (t) design incorporating the integrated approach
- Define features and design requirements of the 1170 MW (t) plant incorporating modifications for increased reliance on passive safety features

Modular Plant Design

- Initiate trade studies of design options to achieve passive safety, competitive economic and operability goals
- Identify technical support programs required for the design of a modular system
- Define technical features and design requirements for an optimized multi-module plant
- Define the program requirements and schedule for the construction of demonstration plant

Technology Development

- Complete the LEU fissile particle prototype process line and demonstrate high product yield through all stages
- Complete the core support performance test in the component flow test loop at ORNL
- Complete the core fluctuation tests in a single-column test rig
- Complete transient condition testing of main circulator bearing and seal assembly
- Complete 1/6 scale model air flow tests of lower plenum, steam generator, and auxiliary heat exchanger inlet ducts
- Initiate specific development programs oriented to proving the capability of passive safety features of the modular system

Spent Fuel Treatment

- Continue development and testing of process steps for prismatic and pebble elements
- Maintain spent fuel handling systems analysis activities in support of HTGR plant activities

NRC Licensing Activities

- Interactions to resolve generic issues and gain acceptance of integrated approach
- Continue safety research and safety criteria development

RECOMMENDED FY-85 NATIONAL PROGRAM FUNDING:

FOR HTGR DESIGN AND TECHNOLOGY	*$52 MILLION*
FOR SPENT FUEL TREATMENT PROGRAM	*$ 4.5 MILLION*
FOR NRC SAFETY/LICENSING ACTIVITIES	*$ 4 MILLION*

Senator DOMENICI. What was the second document you wanted made a part of the record?

Dr. AGNEW. It's called High-Temperator Gas-Cooled Reactor HTGR Program, dated February 1984.

Senator DOMENICI. All right, it will be made a part of the record with your written remarks.

Senator Johnston?

Senator JOHNSTON. I want to welcome you to the committee, Dr. Agnew.

As a supporter of HTGR, I wonder why we can't get more interest from the private sector in an HTGR. Is that because they're just not ordering any reactors at all?

Dr. AGNEW. I think primarily because they're not ordering any systems. I think that the concept of the smaller reactors could be a way of getting the interest, because the total dollar outlay is considerably less.

An interesting point that Bechtel Engineering has come up with; they point out that in a nuclear power plant, 80 percent of the cost is what is called the balance of plants has nothing to do with the nuclear system. Twenty percent of the cost is in the nuclear system. However, present plants are designed such that the safety of the nuclear system is closely interwoven with the balance of the plant. As a result, the balance of the plant at 80 percent has to be constructed to these very high standards of the rest of the plant. That makes the cost very high.

We are looking at separating the balance of the plant safety issues from the nuclear parts. The nuclear part, although it's smaller and it may cost more per kilowatthour of that part since it's only 20 percent, by making the rest of the plant conform to the way other plants are built, coal-fired, oil-fired, gas, whatever you want, the total cost per kilowatthour, we think, will be very competitive with the cheapest of any type of power. And this has an advantage, I think, where the private sector can see they really should get involved.

But I think that right now the reason there are no commitments—the closest was Florida Power & Light in Dade County, nobody's buying anything. But with the smaller plants, because their load requirements are such that they're very antsy about buying 1,000 megawatts if their expectations don't come up to what their planning was, then their public utility commissions won't let them put it into the rate base.

But with the smaller plants, they can sort of work their way up. Also, the smaller plants would allow them to convert coal plants into nuclear plants, because the steam conditions are identical on these plants with the fossil plants. That is not true with the water plants, they're very inefficient, very low temperature.

Senator DOMENICI. Thank you.

Senator Evans?

Senator EVANS. I guess I've just got one question. Why do you feel it's necessary to apparently repeat a lot of the research and development of these gas reactors with all of the experience that's already been teamed in Britian, Germany, Japan, France? Why should we have to do that over again?

Dr. **Agnew**. It's not really being repeated, sir. What is happening is, we have gone to a technology using helium, they've used carbon dioxide; we use coated particle fuel, ceramic fuel, with very high temperatures, they use metal-clad fuel. And in addition to that, since the plants were built early in this country, the NRC regulations have completely changed. Our philosophy in building a plant is, we want to be able to test this plant completely. And we think by testing it under all circumstances, we can completely regain the confidence of the American public and perhaps equally important, the American financial community.

Senator **Evans**. It seems to me that one of the problems we got into with the light-water reactor was we wanted to build them bigger and more complex and do our own thing, and didn't pay much attention to what was going on elsewhere, and they have been enormously successful, and we've flopped.

Dr. **Agnew**. Well, in the gas systems, there's only been two built in this country. We, G.A. Technologies, are in partnership with a German company, Brown, Bavaria, who is building the German plants. We are exchanging their technology. Actually, we have two of our people over in Germany starting up their plant right now. So there's no duplication.

Senator **Domenici**. Senator Ford?

Senator **Ford**. Dr. Agnew, you came forward very quickly, saying that the greatest thing since the invention of baseball was the elimination of acid rain. What causes acid rain?

Dr. **Agnew**. I think from the National Academy of Science report the finger's pointing very much at burning fossil fuels at temperatures above 700 °C. It forms nitricoxides and sulfuric acids. I would say there's no question about it, that that is one of the primary causes of acid rain.

Senator **Ford**. Well, if that was so, the coal industry would be 101 percent trying to get that little problem off their back.

But if you read the Academy's report and you read EPA's report, they're contradictory. Even EPA says you have to have some SO_2 in the air to prevent the greenhouse effect. Now you come in here, trying to sell your operation by knocking something else. I always thought you would sell your product based on how good it was and not be knocking something else.

Senator **Domenici**. Cigarettes also contribute, don't they?

Senator **Ford**. That's right.

Dr. **Agnew**. I'm not knocking the coal. What I'm saying is that we——

Senator **Ford**. I want to tell you, if he'd drink a little whiskey he'd be all right, and it would help our economy, too.

Dr. **Agnew**. Only 2 ounces. Only 2 ounces a day of whiskey is very good for you.

Senator **Ford**. Well, try an apple with that and you'll really have it going.

Senator **Domenici**. Let me ask you about that whiskey. Can you go without for a few days and then double up?

Dr. **Agnew**. I would say that one could, if one were careful.

Senator **Evans**. I'm like the chairman. Once you get critical, you want to keep an even flow.

Senator FORD. See how quickly they get me off of acid rain? [Laughter.]

Well, you know, we don't have much in Kentucky, beautiful women, fast horses, bourbon, cigarettes, and coal. Four of them are habit forming.

Senator DOMENICI. And one of them appears to be deadly.

Dr. AGNEW. Mr. Chairman, I think it would please Senator FORD to know that we at G.A. have also brought into being a fluidized bed circulating combustion for coal which meets all EPA standards, burns at low temperature, and you can use any high-sulfur coal. And we have got one operating in Bakersfield, CA. It's the first coal-burning plant in California. So we're all with you.

Senator FORD. Well, when you look at California and you have only one coal-burning operation out there and they have more acid rain than the rest of the United States. The Devil with blaming it on coal, and start finding out what the real cause is. When you find out the real cause, we'll pass legislation up here to eliminate it so you won't put 45,000 in my State out of work.

I just want you to understand that. I'm here to protect my people. I want your advice, and I want your input, and I want to help you, but when you come in here saying that you want to move at my industry and that sort of thing——

Dr. AGNEW. No; let me explain. On the high temperature——

Senator FORD. We're getting ready to go hear the President of France. You go ahead and I'll listen to him talk about acid rain. Then as soon as I'm through with him, then I'm through.

Dr. AGNEW. OK. The high-temperature gas-cooled reactor allows one to gasify coal. This is why Germany is interested. Right now, Germany is under the thumb of the Russian bear because of the gas deal. Germany has a lot of coal. They're converting to gas. They realize if they get into trouble with the Russians their gas gets cut off and they're in real problems.

They're developing this particular high-temperature gas-cool reactor so they'll have the high temperature process heat so they can process that coal to gasify it, then they can burn it cleanly.

So I'm saying that this particular program helps the coal industry.

Senator FORD. But, Dr. Agnew, we've $15 billion over there in the Synfuels Corporation and we get one contribution, and that's a peat moss operation down in North Carolina, and it's gone on its face.

So we don't get any gasification, we don't get any liquifaction, we don't do anything that's in relation to new sources of energy.

Well, we're here worried about an embargo, and it could happen at any time. And yet we—

Senator DOMENICI. Senator, could I just make an announcement You can stay if you like.

Senator FORD. Yes; I'm going to stay. As soon as I am through with Dr. Agnew, I'm through.

Senator DOMENICI. April 5, for the three other public witnesses, we're having another hearing and we will take you first. The staff will advise you.

Senator FORD. And I'll be back prepared on acid rain.

Dr. AGNEW. I'll leave them answer it.

Senator **Domenici**. Thank you very much. I'm sorry that we're going to do it this way, but that's the way we have to do it today.

[Whereupon, Senators Domenici, Evans, and Johnston leave the hearing room.]

Senator **Ford** (presiding). Dr. Agnew, I hope that you will lend your influence, expertise, and background, and all that, to try to help us become energy independent, and that we not begin to create more of a problem. If we had the acid rain legislation that came out of the Environment and Public Works Committee it would cost the ratepayers in my State alone $700 million annually. Now, that just can't happen.

And when you look at the cause and begin to shoot it down, no one really knows what the cause is. No one will say "this is it." You don't even know how far it travels, or if it travels what happens to it after it gets in the clouds, and where it comes down.

We look at Sudsbury and we look at all these other plants, and yet they point their fingers at the Midwest, and that's got to stop. We have got to find an answer. And I would just say to you that it's going to be a long day before we get any kind of legislation like that through the congress as it relates to reduction of SO_2 emission per million But's generated.

And I would say that if we would all join the President and try to get the research done so we could find some answers we'd all be a lot happier.

Dr. **Agnew**. I agree entirely with you.

Senator **Ford**. With that statement, this hearing is recessed.

(Whereupon, at 3:20 p.m., the hearing was adjourned, subject to the call of the Chair.]

APPENDIX V

RESPONSES TO ADDITIONAL QUESTIONS

Department of Energy
Washington, D.C. 20585

May 3, 1984

Honorable J. Bennett Johnston
United States Senate
Washington, D.C. 20510

Dear Senator Johnston:

With your April 23 letter we received five sets of questions for our response to be included in the printed record. One set of questions related to the March 22 hearing when Assistant Secretary Shelby Brewer testified on the authorization for nuclear energy.

Enclosed are the answers to questions on uranium enrichment and nuclear energy.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas W. Pretorius
for
Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Al Astrin

QUESTIONS FROM SENATOR JOHNSTON

URANIUM ENRICHMENT

Question:	Please provide the Committee with a full discussion of your plans for each of the gaseous diffusion enrichment plants - Paducah, Oak Ridge and Portsmouth - for the coming year.
Answer:	The gaseous diffusion enrichment plants at Paducah, Kentucky, Oak Ridge, Tennessee, and Portsmouth, Ohio, are planned to consume the combined total of 2,790 megawatts of electric power during FY 1985, producing 10.6 million separative work units. We expect the individual power levels would be as follows: Oak Ridge - 800 megawatts, Paducah - 1,075 megawatts, and Portsmouth - 915 megawatts. Since the power levels are below the contract levels, we would expect to pay $339 million in capacity charges for power not purchased.

QUESTIONS FROM SENATOR JOHNSTON

Question: FY 1984 revenues from uranium enrichment sales were about $135 million below your expectations when the FY 1984 budget was submitted to Congress. Could your estimates for FY 1985 be off by this much? Why or why not?

Answer: In the FY 1985 revenue estimate, 96 percent of the Separative Work Units (SWU) are of the Fixed Commitment type of contract, where the customer is contractually obligated to buy Department of Energy (DOE) SWU. Termination charges for partially terminating a Fixed Commitment delivery are severe, and has never taken place.

In the FY 1985 revenue estimate, 4 percent of the SWU are of the Requirement contract type and these customers may terminate their SWU purchase up to the time of delivery. However, there is a termination charge which increases as the date of delivery approaches.

The number of Requirement contract SWU's in the FY 1985 estimate represent less than 10 percent of the SWU needed by customers having Requirements type contracts. Thus, this is a conservative revenue estimate based on the best available information and recent market trends.

QUESTIONS FROM SENATOR JOHNSTON

Question: What are your expectations concerning sales of enrichment services under the new United States Utility Services Contract? What evidence is there to support these expectations?

Answer: We expect between 75 to 100 percent of our customers to convert to the new Utility Services enrichment contract. The degree of acceptance by our customers will depend upon the customers' evaluation of secondary market opportunities, other primary suppliers' contract price and terms, and future prospects for low prices from DOE enrichment facilities. To date, customers who represent about 70 percent of DOE's sales base have indicated an intention to convert.

Of this total, 17 domestic utilities and 6 foreign utilities, representing 41.5 percent of DOE's sales, have formally provided conversion documents to DOE as of April 30, 1984.

Question: How much revenue in FY 1985 is supposed to result from sales under this contract?

Answer: At this time, it is not possible to accurately project how much revenue in FY 1985 will result from sales under the Utility Services contract. With the conversion deadline of October 1, 1984, we expect a high percentage of these revenues to come from Utility Services contract sales.

QUESTIONS FROM SENATOR JOHNSTON

Question: Information provided by DOE indicates that the price the U.S. charges for enrichment services is $20 to $40 per SWU above the prices being charged by Eurodif and Urenco, our foreign competitors. Isn't this just about the amount that each of the existing gaseous diffusion plants have to contribute, on a per SWU sold basis, to the construction program for the Gas Centrifuge Enrichment Plant?

Answer: The existing gaseous diffusion plants, through depreciation and imputed interest, provide revenues that are being used to finance GCEP and other construction activities. In FY 1985 about $8 per SWU comes from these items. Additional revenues to finance GCEP come from imputed interest on GCEP itself and on uranium and separative work inventories.

Question: What are the main factors in the lack of price competitiveness that has contributed to the erosion of the U.S. share of the world market for enrichment services? Provide an analysis of the effects of exchange rates, U.S. construction costs and cost overruns at GCEP, electricity costs and such other factors that you think are significant in determining the overpricing of the U.S. enrichment services relative to those of foreign suppliers.

Answer: The primary factors in the lack of price competitiveness which have contributed to the erosion of the U.S. share of the world market for enrichment services are the strengthening of the U.S. dollar with relation to foreign currencies and the decline in U.S. sales due to secondary market transactions that have replaced direct DOE sales. These two factors are responsible for nearly all of the increase in the DOE enrichment price relative to those of foreign suppliers since 1981.

QUESTIONS FROM SENATOR JOHNSTON

BREEDER BASE PROGRAM

Question: Please provide the Committee with a list of activities in order of priority that the Department intends to undertake to make the best use of the facilities already in existence or under development in our breeder reactor program.

Answer: We are currently restructuring the breeder base program to include work on innovative designs that are responsive to the near term needs of the energy marketplace. Such designs must be economically competitive, place greater dependence on passive safety features, and exhibit reduced construction and licensing times.

The Department will operate the Fast Flux Test Facility (FFTF) to demonstrate the reliability, maintainability, and high plant availability factors inherent in liquid metal cooled fast reactors. A significant activity will be demonstration of a 3-year life oxide fuel core. The Experimental Breeder Reactor-II (EBR-II) will be used to demonstrate inherent safety features in a Liquid Metal Fast Breeder Reactor (LMFBR) as well as to complete the collaborative fuel program efforts with Japan. The Energy Technology Engineering Center (ETEC) will be used to demonstrate the performance of steam generators--which have historically been the largest contributors to plant unavailability in nuclear plants.

In addition, several new initiatives are under evaluation that would provide both increased utilization of the breeder program facilities and meet our restructured program goals.

Department of Energy
Washington, D.C. 20585

May 21, 1984

Honorable J. Bennett Johnston
United States Senate
Washington, D.C. 20510

Dear Senator Johnston:

With your April 23 letter we received five sets of questions for our response to be included in the printed record. One set of questions related to the March 22 hearing when the Acting Director of the Office of Civilian Radioactive Waste Management, Michael Lawrence, testified on the authorization for nuclear waste.

Enclosed are answers to the last part of Question II and the first part of Question III. The answer to the first part of Question II will be sent in a separate letter just as soon as it is completed. Answers to the other questions were sent to you on May 15.

If you have any questions, please call Diana Diamond or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H Pretorius
for
Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Al Astrin

QUESTION II: 3. Whatever the Department's view is, many utility executives believe that the Department of Energy has a legal obligation to begin to accept spent nuclear fuel by January 31, 1998. What does the Department plan to do if that date arrives, but no repository is available to receive the spent fuel? Discuss the legislative authority upon which this plan is based.

ANSWER: 3. The Department is developing contingency plans which could be used to mitigate any impacts caused in the event of repository delays beyond 1998. These contingency plans are to cover potential short-term delays and any major setbacks. In the event of a short-term delay, the Department could assist in the realization of at-reactor storage on a schedule consistent with the timing for removal of these wastes if the repository were not delayed. As noted below, the institutional questions associated with this plan, including funding, licensing and title transfer, have yet to be identified and resolved.

Alternative systems to provide such storage are being investigated using the following criteria:

a. Any such storage must comply with all applicable environmental, safety and licensing requirements.

ANSWER 3. Cont.

b. The transportation and handling of the spent fuel should be reduced as much as practical, and

c. It should be cost effective.

Transportable storage casks have good potential for satisfying these criteria. However, as explained further in response to subsequent questions, licensing and institutional arrangements specific to application of this concept in the United States remain to be worked out.

An alternative solution that has been suggested in the past and that is particularly reponsive to the second criteria, could be to make available to the utilities multi-purpose casks such as transportable storage casks that would also be suitable for emplacement in the repository. A cask with this capability could reduce the requirements for packaging

ANSWER 3. Cont.

and handling at the repository. If such casks are in fact proven feasible, they could be supplied to and used for storage at the reactor sites until the repository could accept them.

A third potential solution, which has some characteristics of both of the alternatives described above, could be to make spent fuel storage containers or canisters instead of casks available to the utilities. The containers would be designed to be a common component of a spent fuel storage and transportation system and, ultimately, part of the package that is emplaced in the repository. If such containers can be made available, they could be supplied to utilities where they would be loaded with spent fuel and stored in a reusable storage or transport "overpack" until the repository could accept them. The container with a suitable "overpack" would be the equivalent of a cask. This concept could also reduce the at-repository packaging requirements.

ANSWER 3. Cont.

If there is a major delay in the commencement of repository operations, the Department plans to propose to provide the required storage in one or more Monitored Retrievable Storage (MRS) facilities. Our plans for development of an MRS capability are discussed further in our response to the questions on MRS.

QUESTION III: 1. Do you believe that this (storage) could be done under the authority provided in the Act? What authority? Please discuss your views.

ANSWER: 1. The question assumes that the Department will have no alternative facility, such as a MRS facility, available on January 31, 1998. It also assumes a prolonged delay in the commencement of operation of a repository. Prior to answering the question, it should be noted that the Department's program envisions having a repository in operation on January 31, 1998. In the event that a prolonged delay in the availability of a repository appears likely, the Department plans to proceed with its program of establishing MRS facilities.

While it is our view that short-term storage in casks in anticipation of transportation to a repository would be permissable under the Act, the Act does not address Federal storage at reactor sites for a prolonged period of time prior to the commencement of operation of a repository.

QUESTION III: 1. B. Is such a plan feasible? For each reactor? Why or why not?

ANSWER: 1. B. We are not aware of any major technical barriers to onsite dry storage of long-cooled spent fuel at reactors, but a number of questions regarding how to implement such an approach remain. On the technical side, sufficient data is available to support the licensing of cask storage in an inert atmosphere. Test programs in progress and planned are expected to provide sufficient basis to license dry storage under less restrictive technical limits than may be initially imposed. Physical space requirements at-reactor site should not be a constraint; less than an acre is required to store up to 200 MT of fuel. At a number of reactors crane upgrading may be required to handle current large cask (e.g., rail cask size) designs. However, some storage options under consideration by utilities can utilize smaller cask designs.

ANSWER 1. B. Cont.

The full range of institutional questions associated with this plan, including funding and licensing arrangements and matters of title transfer, have yet to be identified and resolved. By including the general concept of onsite dry storage at-reactor sites after January 31, 1998 as a contingency plan in the draft Mission Plan, we expect critical comment which will assist in identifying all key issues and problem areas. Once identified, these issues can be examined systematically to confirm the feasibility of the concept.

QUESTION III: 1. C. How would this kind of storage be licensed by the Nuclear Regulatory Commission? What regulations would apply? When would we know how licensing would proceed?

ANSWER: 1. C. Very few of the licensing details for the kind of storage envisioned under this contingency plan have been worked out; only feasibility has been determined to date. Utility spent fuel storage is currently licensed by the NRC under 10 CFR 72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation". If casks are provided and shipments are to be made in these same casks, 10 CFR 71, "Packaging of Radioactive Material for Tranport and Transportation of Radioactive Material Under Certain Conditions", will also apply. If the fuel is stored at reactor sites, physical custody and surveillance activities would probably be performed by utility personnel. In this case the utility would be the licensee under current practice.

ANSWER 1. C. Cont.

Several decisions must be made before it will be known how licensing would proceed. For example, the technology to be used must be selected and matters of title transfer, liabilities, funding, etc., must be settled. We do not foresee a need to finalize these matters for several years, which will allow time to ascertain utility preferences, further examine various technical alternatives, and explore licensing options. The current disposal contracts provide for development of a Waste Acceptance Schedule by 1991. Contingency planning, including detailed plans for providing additional at-reactor storage should the repository receipt rate not reach the rate envisioned in the Waste Acceptance Schedule, will be completed by then.

QUESTION III: 1. D. What role, if any, would the relevant State and local governments have under the Act in "acceptance for disposal" at a reactor site?

ANSWER: 1. D. At a minimum, State and local governments would have the role that is normally afforded them under NRC licensing proceedings prior to at-reactor dry storage. No additional requirements are imposed by the Act. NRC licensing hearings are open and a record of the proceedings is maintained at a local Public Document Room maintained by NRC, usually at a local library. Adequate time is available to determine if a different role for State and local governments is desired or necessary. The Department is open to exploring with the NRC various alternatives that may be proposed by State and local governments for determining this role.

QUESTION III: 1. E. What is the Department's opinion about this plan?

ANSWER: 1. E. The plan is being proposed as a technically feasible, low-cost, low-risk alternative in the event of a short-term delay in deployment of the first repository. The Department considers it worthy of further consideration and development.

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1985

THURSDAY, APRIL 5, 1984

U.S. Senate,
Subcommittee on Energy Research and Development,
Committee on Energy and Natural Resources,
Washington, DC.

The subcommittee met, pursuant to notice, at 9 a.m., in room SD-366, Dirksen Office Building, Hon. Pete V. Domenici, presiding.

Present: Senators Domenici and Evans.

Also present: Paul Gilman, professional staff member; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. PETE V. DOMENICI, A U.S. SENATOR FROM THE STATE OF NEW MEXICO

Senator Domenici. Good morning.

Once again, I would like to apologize for having to recess the nuclear hearing a couple of weeks ago.

We're going to continue with the remaining witnesses from that hearing.

We will start with Mr. Walker, chairman of the Gas-Cooled Reactor Associates, San Diego. We will be happy to hear your testimony now.

We also have Fred Webber, executive vice president of Edison Electric, and we have David Berick, director of nuclear waste, Environmental Policy Institute.

Why don't we have all three of you come up here at the same time.

Thank you all.

Mr. Walker, why don't you proceed.

We will make your entire testimony part of the record. We will be glad to hear from you.

STATEMENT OF RICHARD F. WALKER, PRESIDENT, PUBLIC SERVICE CO. OF COLORADO, AND CHAIRMAN, GAS-COOLED REACTOR ASSOCIATES

Mr. Walker. Thank you, Mr. Chairman. I also appreciate your scheduling this on a day that I have Appropriations Committee, so coming back was certainly no inconvenience and I'm very pleased it worked out that way.

My name is Richard F. Walker. I'm president of the Public Service Co. of Colorado, in Denver, CO. And I'm appearing here today as chairman of the Gas-Cooled Reactor Associates, which is an organization of electric utilities in the United States, representing about one-third of the electric generating capacity.

We were founded in 1978 to help preserve the gas-cooled nuclear concept as an alternative for producing electricity from nuclear energy.

This concept, with its favorable characteristics of high efficiency, greater safety margins, mature compatibility coupled with low-exposure to operating personnel we feel is a viable concept and a very good alternative.

Since nuclear energy is in somewhat of a holding pattern now, due to lower load growth and certain financial restrictions, we think a review of how we use nuclear energy in the utility industry is certainly appropriate.

In 1981, our group picked a standard operating plant, 855 megawatts electric, based upon the combined experience in our group, including the Peach Bottom 40,000-kilowatt gas-cooled reactor, and our Fort St. Brain 330-megawatt gas-cooled reactor, which is operated on my company's system.

We have completed a good conceptual design of this standard lead project plant, the 855-megawatt one. There's some fine-tuning that needs to be done on the design and some interface with the NRC, which we hope to do during this coming year.

A recent survey of our utility group indicated maybe the need to look at some other sizes in the nuclear plant concept. And we surveyed these people, and as a result of that, and in connection with DOE, we feel that maybe looking at a smaller size, something that could be built quicker, something that could be more easily fabricated and, to some extent, tested in manufacturing environment.

So we have come up with two alternatives to our lead plant design which we think warrant consideration during this next year.

The first would be about a half-size plant, something around 400 to 500 megawatts electric. This would be about half of the standard plant that we have already done a lot of the work on, but we think we need to look at it, maybe a optimization, if you're really going to go to that size.

Also, there is considerable interest in a modular type nuclear reactor of the 100-megawatt electric size for possibly they could be put together, maybe four together, five together. Many of the parts could be fabricated in the manufacturing facility and tested, and we think this is something that certainly deserves a look at before we make decisions as to where to go with the nuclear business.

In the coming fiscal 1985 budget, we're proposing that about $15 million be spent on the modular reactor. We have done some preliminary work previously on this, mostly in connection with cogeneration process heat and not this particular application. There is some German experience here, and we hope to look at that.

About $12 million would be spent on a half size of our standard plant. And then the base technology, the work at the labs and some of the other work would mean about $25 million, including about $2 million for R&D facilities, for a total of about $52 million.

The House Science and Technology over on the other side, has finished their report on this and has come out with about this amount of money. And we feel that during fiscal 1985, looking at these alternatives, that we, as an organization of utilities, will have a better idea of where we could go with the nuclear technology. And we are very pleased that Congress has supported us over these trying years, and particularly pleased this year that the Department of Energy is included in their budget, and we look forward to working with them and in keeping nuclear energy as a very viable alternative for we in the electric utility industry.

That's a very short summary, Senator, for the record.

[The prepared statement of Mr. Walker follows:]

STATEMENT SUBMITTED FOR THE RECORD

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

FY 1985 DOE AUTHORIZATION
HIGH-TEMPERATURE GAS-COOLED REACTOR PROGRAM

RICHARD F. WALKER
PRESIDENT OF PUBLIC SERVICE COMPANY OF COLORADO
AND
CHAIRMAN OF GAS-COOLED REACTOR ASSOCIATES

March 22, 1984

Mr. Chairman and Members of the Subcommittee, my name is Richard F. Walker, and I am President of Public Service Company of Colorado and Chairman of Gas-Cooled Reactor Associates (GCRA) which is a utility/user organization that supports the development of the High Temperature Gas-Cooled Reactor (HTGR). At present, the GCRA constituency represents approximately one-third of the installed generation capacity in the U.S. In addition, participating GCRA utilities have a substantial investment in and extensive experience with nuclear power. This background of nuclear experience provides GCRA with a sound base for evaluating the HTGR as a commercial alternative. GCRA's role is to apply this base of experience in guiding the development of the HTGR to be fully responsive to utility/user requirements. A GCRA staff, supported solely by utility funds, has been in place since 1978 conducting HTGR concept evaluations, Project planning and development activities, and Program integration support services to DOE, including the management of architect-engineer resources and other plant-level design development activities.

GCRA's objective is to establish the HTGR as an attractive commercial alternative in a timely manner. The approach to achieving this objective has been to establish a Lead Project from which commercial follow-on plants can be deployed. Despite the recent turmoil associated with nuclear energy, a systematic assessment of candidate HTGR systems, with the participation of potential vendors and owners, culminated in 1981 with the selection of a four-loop, 2240 MWt/855 MWe steam cycle plant as the reference Lead Project candidate. The market for this plant is the medium to large baseload capacity additions for electricity generation or cogeneration of steam and electricity, as well as the replacement market for retiring medium to large fossil and LWR plants. The Lead Project focus established to date has been responsive to the Congressional bases of support and has been instrumental in gaining Program stability. To date, the U.S. government and industry have invested approximately $1.5 billion in the HTGR, most of which is applicable to the Lead Plant. In particular, approximately $50 million has been invested in the conceptual design of the Lead Plant.

The reference Lead Plant candidate, like all HTGR concepts, is characterized by unique features that distinguish it from the current generation of nuclear power systems. The most notable of these features is the inherent safety and low environmental impact characteristics that translate to less reliance on engineered safety systems, added margins for meeting certain licensing criteria, added margins for plant investment protection, greater siting flexibility and reduced radiation exposure of plant personnel.

It is GCRA's position that the 2240 MWt HTGR is a viable candidate for a private sector Lead Project initiative. This position is supported by numerous independent assessments of the design and by operating experience with Fort St. Vrain and other gas-cooled reactors throughout the world. Confidence in the industry's ability to construct and operate plants of this size comes from recognition of the successes experienced by nuclear qualified utilities with large nuclear power facilities in the U.S. and abroad. Ongoing programmatic activities should emphasize the application of the conceptual baseline documentation, to be completed in FY 1984, for substantive pre-review interactions with the NRC on HTGR-specific licensing criteria.

During the past year, there have been a number of introspective studies and surveys, including a broad utility survey by GCRA, on the future of the nation's nuclear power industry. A recurrent message from these efforts is the need for the development of smaller, simpler nuclear power plants with minimal reliance on engineered safeguard systems. Within the HTGR Program, smaller alternatives to the 2240 MWt system have been identified that offer added dimensions of simplicity that may translate to overall performance and economic advantages. In one approach, a 1170 MWt/425 MWe design has been configured that was originally conceived simply as a two loop version of the reference four loop Lead Plant. However, with an emerging market interest in plants of this size range, an optimized version of an HTGR in this size range should be evaluated. Some of the key areas that must be addressed are as follows:

1) The approach to decay heat removal, including the use of passive systems.

2) The number and size of primary system coolant loops, the configuration of the PCRV and the ability to use a confinement rather than a containment-type enclosure.

3) The optimum approach to multiple unit plants and the sharing of common systems and facilities, plus greater use of modularity and conventional plant construction standards.

4) The closer evaluation of the features of the German HTR-500 (MWe) concept that is targeted for project commitment decisions by the end of 1985.

In the second alternative to the 2240 MWt system, an HTGR Modular Reactor System (MRS) has been conceived as independent reactor units of approximately 250 MWt/100 MWe that can be constructed as a cluster of modules or sequentially constructed to more closely match load growth requirements and reduce utility cash flow needs. Design work on the MRS is relatively recent, and less than $5M has been invested in defining and evaluating the concept. However, much of the technology investment for the Lead Plant is applicable for the MRS. Further, much of the HTGR technology investment in the Federal Republic of Germany, including the AVR developmental plant and the THTR demonstration plant, is expected to be particularly applicable to the MRS concept.

The intent of the MRS concept is to achieve greater inherent safety by removing the decay heat by the passive mechanisms of radiation, conduction, and natural convection without reliance on active engineered safeguard systems. The concept is based on limiting the core size and power density such that the fuel particle coatings retain the fission products to an acceptable degree (yet to be defined) under all circumstances, including the loss of all forced circulation or the failure of the pressure boundary. The economic challenge of the MRS concept is for the design simplicity afforded by the passive safety attributes to offset the economy of scale advantages of larger, integrated nuclear plants. To do so, it is intended that the nuclear steam (or heat) supply system will be shop fabricated to nuclear standards and the balance of plant field erected to predominantly conventional fossil plant standards. This approach is expected to improve the low productivities, reduce the schedules and reduce the field erection costs encountered on most of the recent nuclear projects.

The MRS concept is in the early stages of evaluation. Some of the key issues that must be addressed are as follows:

1) Sufficient design must be conducted to support economic analyses that will examine sensitivities in the costs and schedules for the modular HTGRs versus the integrated HTGRs and the other alternatives.

2) The safety goals of the MRS must be specifically defined and translated to licensing requirements and engineering terms. Key issues are the development and acceptance of design basis events, source terms and allowable fission product releases.

3) The design and development programs required to demonstrate the unique, inherent safety features of the MRS must be defined. Central to the MRS concept is the use of a fuel for which high integrity and low fission product release can be assured under all postulated reactor conditions. These design requirements place provisions on fuel manufacturing and performance that require extensive verification.

If commercial feasibility of the MRS is established, it is envisioned to serve the small to medium baseload generation and cogeneration markets as well as the replacement market for some of the retiring oil and gas-fired units that have been used for baseload applications. Further, the unit size of the MRS makes it particularly attractive as an export product to developing nations. It is GCRA's view that the MRS concept has significant technical and licensing potential. If economic incentives for the MRS are borne out in thorough technical studies, there will be justifiably strong utility/user support.

Common to any of the HTGR concepts and potential Lead Projects is the need to address the key institutional issues of licensing reform, vendor development, program management and Project development responsibilities, and long-term budget stability. With regard to the latter issue, we are most heartened that the DOE has included the HTGR Program within their FY 1985 budget proposals to Congress at a level of approximately $35 million.

In order to complete the concept evaluation of the mid-size integrated plant and the MRS by the end of FY 1985, we respectfully recommend that the HTGR Program at DOE be funded at an increased level of $52 million in FY 1985. In particular, GCRA estimates a $15 million effort will be required to complete the ongoing MRS concept evaluation. For the ongoing integrated plant design effort, GCRA estimates a $12 million effort will be required in FY 1985 to evaluate a mid-size plant and to establish the overall optimum approach for an integrated HTGR design. Pending a positive outcome from this effort, a Lead Project conceptual design could start in 1986. During this period, the technology development programs should be maintained at a level of $25 million, including $2 million for R&D equipment. The emphasis of the technology development should be toward the resolution of the critical technical and licensing issues that affect any Lead Project commitment decision. In addition, the HTGR spent fuel treatment program at DOE should be maintained with continued emphasis on spent fuel volume reduction, storage and disposal. In parallel with the DOE-funded development activities for the integrated and modular HTGR designs, ongoing Lead Project site and institutional development activities will be continued by GCRA and other prospective Project participants with the goal of selecting the optimum Lead Plant system by the end of FY 1985. Utility resources through GCRA have continued to increase in this area with approximately $2.5 million contributed in 1983 and approximately $3 million budgeted for 1984.

On the local front, I am pleased to report that 1983 has been another year of improving performance for Fort St. Vrain. As you know, the the Fort St. Vrain power plant first went critical in January 1974, achieved a 70% power level in January 1978, and was limited to that level by the NRC. In November 1982, after an extensive corrective program was completed by GA Technologies to resolve core temperature fluctuations, the NRC granted authorization to routinely operate at 100% power. In addition, the Public Service Company of Colorado continues to make investments in the plant that support its continued invaluable demonstration role. In 1983, we spent approximately $10 million and $9.3 million has been budgeted for 1984.

Fort St. Vrain has provided critical confirmation and demonstration of many key HTGR concepts. In particular, fuel integrity and radiation exposure to plant personnel have had an exceptional operating record. Operating data indicate that the amount of radioactivity carried in the helium coolant has been less than two percent of the design limit, demonstrating the structural integrity of the coated fuel particles and the graphite core structure. A comparison of personnel exposure data for Fort St. Vrain and light water reactor plants in the U.S. indicates that Fort St. Vrain has had an average annual person-rem exposure rate per GW(e)-year of approximately two orders of magnitude less than the average exposure rate in light water reactor plants. This low personnel exposure level is even more significant in view of the fact that Fort St. Vrain has virtually unlimited access into the reactor building for all operations and maintenance personnel. Other major contributions of Fort St. Vrain have been in the areas of core physics confirmation, plant control and response, and plant performance. Plant operating experience to date has demonstrated predictable performance even during extreme modes of operation, including temporary loss of forced cooling. The high core heat capacity has shown temperature transients to be slow, predictable, and easily controlled. Operation to date has achieved 1400°F primary loop helium temperatures, 1000°F steam temperatures, and a net efficiency of 38.5%--the highest of any nuclear plant in the U.S. As of year-end 1983, the Fort St. Vrain plant has delivered approximately 3.8 billion kilowatt-hours of net electrical energy, and in 1983, the plant exhibited its most satisfactory continuous run. We are confident that Fort St. Vrain will continue to provide valuable kilowatt-hours for our customers as well as critical information regarding the demonstration of many HTGR systems and components. My Company is proud of our role as owner/operator of Fort St. Vrain.

Mr. Chairman, we appreciate the opportunity to present the utility/user support and perspective on the HTGR Program to your Subcommittee. With your continued support, we will bring to fruition an HTGR Program that is responsive to utility needs and the Nation as a whole.

Senator DOMENICI. Mr. Walker, when do you have to be at the other hearing?

Mr. WALKER. At 10 o'clock, sir. We have plenty of time.

Senator DOMENICI. Why don't you wait and let's see if we ask you something when we're finished here.

Fred Webber, executive vice president of Edison Electric. We're glad to have you, and your statement will be made a part of the record.

STATEMENT OF FREDRICK L. WEBBER, EXECUTIVE VICE PRESIDENT, EDISON ELECTRIC INSTITUTE

Mr. WEBBER. Thank you, Mr. Chairman.

My testimony is provided on behalf of the Edison Electric Institute, the American Nuclear Energy Council, and the Utility Nuclear Waste Management Group. I'll summarize the statement and request that the full written statement be made part of the record of the hearing.

First, I'd like to present some specific facts to indicate the past performance and future productive potential of commercial nuclear energy.

Nuclear energy is a necessary and essential part of the Nation's energy. Last year some 13 percent of the Nation's electricity was generated by nuclear energy plants, and this figure is expected to reach about 20 percent before the end of the century.

With a growing economy and the unusual weather this past year, we experienced electricy output for 1983 that was 3½ percent greater than 1982, and the peak load for the Nation overall went up by about 7½ percent; more than double our highest earlier forecasts.

We would respectfully submit that nuclear energy plants are necessary to provide the electricy in the future for a growing economy.

Concerning the Nuclear Waste Program, the electric utility industry was pleased to have accepted its responsibility under the Nuclear Waste Policy Act of 1982 by signing contracts with DOE and providing funds at a rate of over $300 million a year—I should say this year.

Revenues from utility payments will add up to $15 to $25 billion, making this Federal program one of the largest civil works projects ever undertaken by this country.

We are concerned about whether all other parties are upholding their part of the bargain as defined in the language as well as the spirit of the act.

The Department of Energy appears to be overemphasizing process at the expense of the schedule established by the act.

Both are essential, and it is vital that DOE start taking spent fuel from the utilities in 1998. The Department of Energy is proceeding effectively to prepare the material on the monitored retrievable storage concept for submittal to Congress by July 1985.

The MRS concept is viewed as a parallel effort to the waste repository, and it may be advantageous to have an MRS if substantial delays are encountered with a respository program.

DOE has achieved substantial accomplishments during the first year of this multidecade project. However, there are several areas of real cncern about the program that need serious attention and serious attention soon.

Concerning uranium enrichment. The utilities purchase uranium enrichment services from the Department of Energy full-cost recovery basis.

Unless the Department took substantial corrective actions it's program would have resulted in major market losses. During the past few months, DOE did develop a market-oriented contract that is probably the most suitable arrangement that can be provided.

We believe the newly announced utility service's uranium enrichment contract is reasonable and appropriate. Also, we recognize the need to develop more efficient enriching technology to maintain a competitive position and to minimize overall cost.

We support the continuation of the gas centrifuge enrichment project at a reduced level until a selection is made in mid-1985 on the preferred advance technology.

Concerning Three Mile Island. The cleanup of Three Mile Island, too, must and will be achieved. DOE assistance on this effort is essential, and we urge full support for this budget item.

Concerning nuclear licensing process improvements. The nuclear licensing process must be changed. Areas of immediate concern in the licensing arena are the need for issuing temporary operating licenses, and a resolution for emergency planning where a locality and State do not cooperate.

As for breeder reactor systems, breeder reactors continue to represent the best apparent technology to satisfy the long-term need of assured electricity supply that can be available for many centuries.

The DOE breeder program should be directed toward those research and development programs that have the greatest potential payoff.

Funds should be made available and concentrated on those tasks that will expand our technological base on breeder reactors and the accompanying fuel cycle.

[The prepared statement of Mr. Webber follows:]

EDISON ELECTRIC INSTITUTE
AMERICAN NUCLEAR ENERGY COUNCIL
UTILITY NUCLEAR WASTE MANAGEMENT GROUP

TESTIMONY BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
UNITED STATES SENATE
ON THE
DEPARTMENT OF ENERGY BUDGET REQUEST
FOR FISCAL YEAR 1985
MARCH 22, 1984

Mr. Chairman and Subcommittee members, my name is Fred Webber, Executive Vice President of Edison Electric Institute. My testimony is provided on behalf of the Edison Electric Institute (EEI), the American Nuclear Energy Council (ANEC), and the Utility Nuclear Waste Management Group (UNWMG). EEI is the association of investor-owned electric utility companies and its members generate about 76 percent of the electricity in the United States. ANEC represents over 100 organizations having an interest in nuclear power, including private, public and cooperatively-owned utilities, manufacturers, architect-engineers, and various firms in the nuclear fuel cycle. UNWMG is a specific activity that is funded by forty-two utilities with nuclear programs, including EEI member companies, public utilities, and cooperatively-owned utilities with the sole objective of assisting in the resolution of spent fuel storage and nuclear waste disposal issues.

Today I want to emphasize a number of specific points regarding the DOE activities on nuclear waste and uranium enrichment programs that are being paid for by funds from electricity customers through fees paid to the Federal Government by the electric utilities. Then, I will highlight several other elements of the DOE nuclear programs of specific interest to our industry.

Recent Facts on Nuclear Energy and Electricity Demand

First, I would like to present some specific facts that provide a balanced view on the past performance and future productive potential of commercial nuclear energy in the United States as a necessary and essential part of this nation's energy picture.

Despite the recent publicity concerning problems being encountered at several nuclear power plants, nuclear energy in the United States is a productive technology. Last year, some 13 percent of the nation's electricity was generated by nuclear energy plants. In ten years we estimate the national figure to reach about 20 percent, with nuclear energy being second only to coal in serving the nation's essential electricity generation.

We have 76 nuclear reactors in commercial operation--more than any other nation in the world. Six others are in the start-up phase of operation. An additional 41 units have construction permits with scheduled completion dates.

In 1984, as many as 15 of these 41 units could be ready for operating licenses. Several of these probably will slip over into 1985 before their licenses are obtained. The other 26 units have scheduled completion dates extending from 1985 through 1990.

Nuclear power has saved billions of dollars for the electric customers of this nation. If the electricity supplied by nuclear plants between 1974 and 1982 had been provided instead by coal or oil plants, consumers would have paid between $13 billion and $75 billion more, depending on the type of fuel substituted.

Twelve months ago, based on what we knew then of the recession and the likelihood of the economic recovery, the electric utility industry predicted that during 1983, electric output or sales might increase 1½ percent to 2 percent and peak demand might be 2 to 3 percent higher than 1982. However, the economic recovery was much stronger than most experts anticipated and the weather set records for both heat and cold. What actually happened was the electric output for 1983 was 3½ percent greater than for the preceding year and the peak load for the nation overall went up 7½ percent--more than double our highest earlier forecast.

Mr. Chairman, nuclear energy plants are necessary. We will need more electricity in the future to help drive our recovering economy and maintain our standard of living. Conservation, load management and renewable energy sources are essential and helpful, but, they are simply not enough. Also, we cannot rely just on coal to provide additional capacity and to replace aging facilities. We must use nuclear energy now and must put in place the necessary process to permit its expanded use. Licensing reform legislation is essential to permit both coal and uranium to be available as fuel choices in the future.

Nuclear Waste Disposal Program

At this point, I would like to discuss the electric utility involvement in the nuclear waste program. Utilities are presently making payments to the Nuclear Waste Fund of about $25 million each month, and this will increase to about $50 million each month as the plants under construction are brought on line. The overall program will last as long as there are nuclear wastes to be disposed. Revenues from utility payments will add up to $15 to $25 billion dollars, making this program one of the, if not actually the largest civil works project ever undertaken by this country, that will extend over many decades and funded with a user fee on electricity.

Since utilities are providing essentially all of the monies for the program, amounting to several hundred million dollars each year, it behoves us to perform, on behalf of our electricity customers, some form of a watch dog function over DOE to assure that the monies are being spent effectively and efficiently. We believe that our interest is directly in line with that of Congress, to achieve the disposal of nuclear waste in a safe manner, on a timely basis, and with an efficient and effective program that allows for state and public involvement in the decision making process. Mr. Chairman, we feel that by performing an effective industry overview effort, we will be better equipped to provide comments and recommendations on the nuclear waste program to Congress, the Administration, our electricity customers and our stockholders. We want to provide the funds for the program, however, we insist that proper controls be provided over its cost and that the schedule is achieved. It is vital that DOE starts taking our spent fuel in 1998.

Our industry worked closely with many Congressional committees over a period of several years to bring about the enactment of legislation that we know as the Nuclear Waste Policy Act of 1982 (the Act). The utilities are pleased to have accepted their responsibility under the Act by signing contracts with DOE and for the past several months have been providing funds to the Federal Nuclear Waste Fund. Our concern extends to whether the Congress, the Administration, DOE, the states, and all other parties, including special interest groups are upholding their part of the bargain as defined in the language, as well as the spirit, of the Act.

Many compromises were made during the development of this landmark legislation. While each one of us would have preferred legislation more to our own particular liking, we accept the legislation as passed and will work to see that it is carried out as effectively and efficiently as possible. We do not believe that any change should be made in the legislation in the near-term. Moreover, due to the legislation's complex nature, it should not be amended ad hoc, but rather only through comprehensive hearings before the relevant committees of jurisdiction.

We are concerned that there is a tendency in the Department of Energy to over-emphasize process at the expense of the schedule established by the Act. This is reflected in a recent draft of the DOE Mission Plan for the waste management program. The draft Mission Plan not only specifically places a priority on process over the schedule prescribed in the Act, but proposes to slip the schedule for achieving significant milestones. For example, the Plan proposes to delay the recommendation to Congress by the President for the first repository site from March 31, 1987--as mandated in the NWPA--to December 1990. This is a delay of almost four full years or three years based on the extension provided in the Act. This length of delay does not appear appropriate or necessary, and specific direction should be provided by Congress to minimize any such delays. Under section 114e, any Federal Agency that is unable to meet a Congressionally mandated schedule is required to report to Congress on the reasons for the delay, and to take steps to mitigate its impact.

Although we support the need to proceed through the process called for in the Act with detailed recognition of all concerns, we do not believe the schedule should be secondary. Having the first repository by 1998 is very important, and many intermediate steps must be achieved on a timely basis for this to happen. DOE should move aggressively to re-establish the schedule to match as closely as possible the dates prescribed in the Act and to reassert its determination to comply with the timetable for reaching future milestones. We will be watching this matter closely and believe that Congress should carefully monitor progress against the backdrop of the timetable as a "vital sign" of the health and condition of the program.

Also, we are concerned, about the special interest pressures that are being brought to bear on DOE to influence the direction of the program in ways other than mandated by Congress. We have observed pressures being applied on DOE to achieve preferences within its Site Selection Guidelines for certain potential host states to gain an advantage that they were unable to gain from Congress. This has resulted in a delay in the issuance of the Guidelines. Other pressures are evident by research organizations to continue the past practice of researching everything, rather than to proceed with a definitive effort to resolve problems of geologic disposal in a timely manner. Contractors are developing the primary programmatic input to the DOE offices. While the contractors are intimately involved in developing programmatic details, the utilities that are providing the funds often are denied access to such details until after the plans are in place. We believe the utility industry can make a significant contribution to the overall program by being allowed to participate early in the programmatic planning process.

Proceeding with a waste repository is the direction for the nuclear waste program that is preferred by the electric utility industry. However, we support the legislated direction to consider the need and feasibility of a monitored-retrievable storage (MRS) facility. DOE is proceeding effectively to prepare the material on the MRS concept for submittal to Congress by June of 1985 to permit Congress to determine whether an MRS facility should be incorporated in the overall nuclear waste program. The MRS concept is viewed as a parallel effort to the waste repository, and it may be advantageous to have an MRS if substantial delays are encountered with the repository program. Also, it may turn out that an MRS in conjunction with a repository is more economically attractive for the overall waste program.

Mr. Chairman, I would like to comment on one additional matter pertaining to the Act. That is, the size of the program and how it should be managed. The question of whether a decentralized approach of DOE management is the proper one to control such a large project is still open. The foresight of Congress in calling for a study to review and evaluate alternative organizational structures for carrying out this enormous task was fortuitous. While the study will be completed later than originally requested, it should be a valuable input to defining the preferred type of organization to carry out this very large and difficult task. Regardless of whether the study suggests a need for a separate organization, it appears that a strong, central control project office with substantial control over field activities is needed to assure the effective and efficient control of the program.

Stability is essential for the leadership of a successful program and a strong central project control appears to be needed to satisfy all aspects, institutional, political and technical, with good coordination and still achieve a reasonable time schedule with responsible cost control. DOE must be encouraged to resist such things as individual pressures for pet projects, perceived new and better alternatives, desires to research every concern forever and the strong efforts to achieve a preferred position by all potential host states.

The Fiscal Year 1985 Budget Request indicates that DOE is planning increases in the one mill per kilowatt hour fee because of an estimated revenue shortfall. Congress, as well as ourselves, need considerably more supporting justification than is contained in the sketchy budget document before an increase should be permitted. Congress anticipated that the revenues would not match the expenses in every year by permitting the program to borrow money from the U.S. Treasury or, in the case of having excess funds, invest in Government securities. The program is to achieve full cost recovery over its life and the fee is to be determined on that basis. The self-imposed requirement of the Administration that the revenues must exceed the expenses in all early years is a burden that does not appear compatible with the legislation.

There are many other aspects of the program that could be discussed; we have touched upon only a few. In fact, we commend the Department of Energy for its substantial accomplishments during the first year of this multi-decade project.

The DOE progress includes:

o Major program changes to address the deliberate process steps of the legislation to overcome the institutional and political barriers.

o A separate Office of Civilian Radioactive Waste Management has been established within DOE and its Director reports to the Secretary.

- Seventy contracts were signed by June 30, 1983 with owners and generators of nuclear waste.
- Monies are being received into a Nuclear Waste Fund at a rate of about $25 million each month.
- Six states have been notified they have potential sites for the first repository and seventeen additional states notified regarding the second repository site.
- Siting guidelines have been prepared and submitted to NRC for concurrence.
- A draft of Volume I of the Mission Plan covering overview and current program plans has been prepared and provided to interested parties for early review and comment.
- Study and design work have been initiated for a Monitored Retrievable Storage (MRS) facility.
- Cooperative agreements have been established with three utilities for development of new on-site storage concepts for spent fuel.

While the pace of DOE efforts may be less than desired, the legislation did establish a very difficult road map and it appears that DOE has been carefully negotiating its way through the mine field for the initial steps of this program. However, the following summarizes several areas of real concern about the program. It may be appropriate to take specific initiatives to assure that they are addressed effectively.

- A permanent Director has not been nominated, and all except one person in the upper level management are designated as in an acting capacity. The assignment of top quality permanent management personnel is necessary to get the task accomplished.
- Establishment of a detailed project plan and decision schedule is essential. A definitive and detailed repository schedule has not been provided that places the necessary emphasis on the critical path items to assure the availability of a repository in 1998. DOE concedes that it will not achieve the selection of the first repository site by 1987 as called for in the Act.

- It appears that a strong, central control project office with substantial control over field activities is needed to assure the effective and efficient control of the program. Such is not the way that DOE performs its normal business activities.

- National Laboratories, academicians, consultants and contractors appear to be spending funds rapidly on time and material, open-ended arrangements. It appears desirable to urge that fixed cost contracts with incentives and penalties be pursued for a majority of the expenditures.

- States are requesting specificity in the Site Selection Guidelines in their effort to obtain a preferred position for their state. Preferences beyond that legislated in the Act must be resisted by DOE and NRC.

- Process and schedule details are provided in the Act and DOE should not place emphasis on one over the other.

- Full cost recovery for the program is essential and any change in the fee being paid into the Nuclear Waste Fund must be based on a detailed evaluation that is fully supported to achieve a balance over the complete program.

Uranium Enrichment

Uranium enrichment services, in the form of separative work units (SWU) are purchased by electric utilities as a necessary part of the nuclear fuel cycle to increase the percentage of the fissionable uranium isotope, U-235, from its natural concentration of 0.711% to approximately 3-5% for use in the typical light-water reactor. Up until about ten years ago, the United States Government held a virtual world-wide monopoly in the market for uranium enrichment services provided to non-communist countries. However, for a number of reasons, including Congressional and Administration actions, the non-U.S. market share held by DOE has dropped, over the past decade, to about 35 percent. The original U.S. contracts for enrichment services (Requirements Contracts) were market-oriented and permitted the customers to purchase the service as it was needed. These contracts, while still in effect for those utilities that hold them, were not offered after December 1972. In September 1973, the Long-Term, Fixed-Commitment contracts were offered as the only type of contract available from the U.S. Government. These contracts, as the name implies, were take-or-pay arrangements that forced the customer to purchase services, based on a ten-year advance projection that could not anticipate what would occur, whether or not the enrichment services would be needed to fuel the operating plants. Many of these contracts were taken by utilities because they had no alternative source. Later, foreign competition, in the form of two European consortia (Eurodif and Urenco), was developed with similar contractual arrangements. An attempt was made in 1975, by the U.S. Government, to correct the obvious imbalance between contracted supply and actual demand by offering a short "open season" to allow adjustments to contracted deliveries. Most utilities availed themselves of this opportunity, but the overall effect was not sufficient to correct the market imbalance. Therefore, in May 1978, the Adjustable, Fixed-Commitment contract was offered, which allowed some flexibility. Even these contracts resulted in electric utilities having to purchase unneeded enrichment services under take-or-pay arrangements. Any excess costs associated with these take-or-pay arrangements are borne by the electric utility customer in the cost of nuclear fuel.

As a result of this forced imbalance in the market, a large surplus of enriched uranium came about in the United States and overseas. Since there is only one use for low-enriched uranium, that is to produce electricity in power reactors, at some time a market correction was going to come about. This happened in earnest during the past couple of years by a combination of contract terminations by the customers holding the originally offered Requirements Contracts and their subsequent purchase, largely from foreign sources and at a discount, of enrichment services from those customers holding the take-or-pay contracts. This was a natural market correction that was outside of the control of the producers and DOE was faced with major revenue losses.

About one-half of DOE's enrichment contracts permit terminations such that customers can purchase SWUs elsewhere. The result is that one-half of DOE's business has the potential of being cancelled. In fact, DOE is losing about 15 percent of its planned business in FY 1984.

DOE must, by law, operate the enrichment program on a full cost recovery basis. As it loses business it must spread its costs over a shrinking base of customers. The net result is potential, large price increases to DOE customers who cannot take advantage of the secondary market because of contract-type or company policies.

DOE is carrying out several major investment programs to develop and install newer technology that has the potential to bring down enrichment costs. DOE is constructing the Gas Centrifuge

Enrichment Plant (GCEP) at Portsmouth, Ohio. This plant will employ technology that uses only one-twentieth of the energy used by the current gaseous diffusion plants; energy is currently about 50 percent of DOE's enrichment costs. The electric utility industry has always supported GCEP as the only near-term alternative to gaseous diffusion that will, with certainty, start to bring down, in real terms, the cost of enrichment. This would help DOE's competitive position in the enrichment services market. DOE is also continuing the development of Advanced Gas Centrifuge (AGC) technology that has a potential for greater cost savings over the cost of diffusion technology. On a longer term basis, DOE is researching the Atomic Vapor Laser Isotope Separation (AVLIS) process, which might show cost advantages over AGC. However, AVLIS only now is moving out of the laboratory stage and any projections regarding its performance must be viewed skeptically.

Furthermore, by Office of Management and Budget requirements expenditures must be fully covered by SWU sales revenues. The yearly pricing calculation of DOE, however, cannot explicitly include future construction and development costs. Therefore, the cash required to pay for future technology development and construction is generated by including in the price such standard accounting items as depreciation and imputed interest.

The DOE uranium enrichment program is faced with many constraints, some self-imposed and some legally required. It is evident that unless changes are made, the DOE enrichment customers and, thereby, the electric ratepayer would continue to pay for DOE's inability to respond to market changes, and DOE and its customers would lack any reasonable predictability for DOE enrichment services.

DOE responded by initiating, in early 1982, a review of its most current contracts and holding discussions with its customers in an attempt to develop a more flexible commercial vehicle. Over these past two years, DOE published two draft contracts, held numerous discussions with customers, and received a great amount of input. The input from the customers has been consistent: DOE must develop a contract that recognizes the enormous, worldwide imbalance between supply and demand of enrichment services. If a new contract was not developed that would allow a controlled balancing of supply and demand, strong market forces would do so in an uncontrolled manner doing severe damage to DOE and its customers in their wake.

In response to the requests of its customers and the growing pressure from the secondary market, especially in the past six to eight months, DOE crafted what is probably the most suitable contract, giving consideration to the customers' needs and DOE's constraints.

The Edison Electric Institute, whose members include the vast majority of DOE's domestic enrichment customers, believes that the newly announced Utility Services (US) uranium enrichment contract is a reasonable contract and, while each utility must make its own decision on conversion from its current contracts, we are encouraging our members to give the US contract the serious consideration it is due. The US contract provides the utilities with enough flexibility to deal with over-stocked inventories, without depriving DOE the revenues it needs to maintain services and continue the future construction and development that is vital to contain the future cost of uranium enrichment. We applaud DOE for its efforts and believe that they have properly addressed the issue.

We are pleased to note that Duke Power Company, one of DOE's largest customers, was the first customer to execute a conversion to the new US contract, and that DOE has received letters of intent to convert to the new contract from many domestic utilities. While firm estimates will not be known until contract conversions are complete, we estimate that savings to all electric ratepayers will be in the range of several hundred millions of dollars. The new US contract appears to be beneficial to the domestic ratepayers, to the balance of trade for the nation, to achieving an enrichment program that is responsive to the overall market needs, and to encourage the proper allocation of limited Federal resources.

This new contracting activity will require an adjustment to the DOE program for building more efficient uranium enrichment capability. The DOE FY 1985 Budget Request documents indicate that the size and scope of the program will be driven by the market response to the new contract and attendant revenues. We endorse this approach and eagerly await the outcome of the contract conversions and DOE defining the future program. Since the new contracts have been available for less than one month, and the conversion by present customers can be accepted until the end of September, it is too early for DOE to determine the revenues that will be available during Fiscal Year 1985.

We are vitally interested in having the most efficient and dependable enriching technology available for our member companies. One of the messages the utilities sent to DOE over the course of the last six months was that if DOE offered a new contract that was the right contract, the market response would be such that sufficient revenues would be produced for DOE to continue funding the vital construction and development for the future. When DOE does propose its future operating program details and its program for developing more efficient capability, we will want the opportunity to evaluate the plans and comment on them. In the meantime, we support the continuation of the Gas Centrifuge Enrichment Project (GCEP) at a reduced level until a better understanding is provided on the actual contract situation and an opportunity is provided for the review of the technology choices for improved efficiency. From what we know about the technologies at this point, most if not all of the potential efficiency improvements can be achieved with Advanced Gas Centrifuge technology, while retaining a conservative approach to achieving a reliable long-term supply of enriching services at a reasonable cost.

DOE has indicated that it will make a technology choice in mid-year 1985. It is currently developing a plan for making this determination. Our vital interest in this decision compels us to request an opportunity to participate in the process. We want the choice to be made in a manner consistent with the best interests of those to be served by the decision--the electricity customers.

Three Mile Island Activities - The cleanup of TMI-2 must and will be achieved. All of the contaminated water has been processed through chemical filters to remove the radioactivity, and the surfaces are being decontaminated inside of the containment building. The next major activity is the removal of the head from the reactor to permit access to the damaged fuel. DOE assistance on this effort is essential and we urge full support for, or expansion of, this budget item.

Nuclear Licensing Process Improvements - The nuclear licensing process must be changed to achieve earlier public participation, remove uncertainties in the process, provide hearings on those issues that truly affect public health and safety, encourage the use of standardized plant designs and perhaps the most important element is to create a sensible, systematic and documented approach to the imposition of backfitting. A careful examination of the licensing and regulatory system provides ample evidence that it evolved, and continues to evolve, in a largely undisciplined manner. This is inconsistent with the large and still growing number of nuclear power plants. Therefore, the primary objective of regulatory reform should be, consistent with the health and safety of the public, to eliminate the inefficiencies in the current process. Such action will assure the continued safety of the public.

As discussed earlier, our country's economy will grow, and so will the demand for more electricity. This linkage is vividly evident over the past few years. While total energy consumption in the nation has gone down, electricity consumption continues to grow in a manner that is related to economic growth. This growth can be partially accommodated by further conservation, load management and the use of renewable energy resources. But we will need new capacity and only two fuels, coal and uranium, are available for major expansion. Relying only on one of these would be foolhardy. Licensing reform is essential to permit both fuel options to be available in the future.

Several specific licensing issues are of immediate concern to us:

- One large nuclear plant will be completed and waiting for an NRC approval to load fuel this year while the Hearing Board continues its scheduled deliberation on the plant that extends several months beyond the time that an operating license is needed. This is an obvious case of a need for NRC permission to issue a temporary operating license.
- A second issue is the continued refusal of a locality and the state to cooperate in the preparation of an effective off-site emergency response plan in the vicinity of a nuclear plant. They, in effect, have achieved a veto authority over safety aspects of a nuclear power plant operation, which has been held as a Federally pre-empted authority since the passage of the Atomic Energy Act of 1954. A means is needed to overcome the outright refusal to cooperate by a locality or a state.
- A third issue is that the NRC is taking an unusual and what appears to be an inappropriate approach to satisfy Section 306 of the Nuclear Waste Policy Act of 1982. This section of the legislation calls for greater emphasis on the training of nuclear power plant operators, and all or part of it could be satisfied with regulatory guidelines. NRC appears to be expanding on this and developing new rules and regulations for nearly all persons working at a nuclear power plant. This flies in the face of the utility industry efforts in this area. Prior to the accident at TMI-2, the NRC regulated training only for reactor operators. Then the Institute of Nuclear Power Operations (INPO), was set up by the industry with one of its primary functions

to address the area of training for key nuclear plant positions. The industry, through INPO, has taken initiative in establishing training programs for other nuclear plant positions, as well as licensed operators. Considerable progress and momentum has been achieved. We believe that INPO is doing a credible job of industry self-regulation in the training area. New NRC regulations in this area could undermine the INPO/industry initiative. This appears to be a direct step of over regulation by NRC, beyond that called for in the legislation, that is a disincentive for further industry efforts of self improvement through organizations like INPO.

- Another area of critical concern is the NRC Interim Policy Regarding Investigations and Adjudicatory Proceedings. This interim policy addresses the situation where allegations have been made to the NRC about a particular plant and that plant is subject to an ongoing licensing hearing. The policy would permit the hearing boards to receive information from the OI investigators about the allegations and the status of their investigation in closed sessions without the presence of, or disclosure to, other parties to the proceeding. This policy appears to violate the rule prohibiting *ex parte* communications in the Administrative Procedure Act and the NRC's rules and appears to be inconsistent with basic due process.

- Also, in some cases the, NRC's policy and procedures for resolving allegations in nuclear power plant licensing cases are being abused in an apparent attempt to forestall or prevent timely NRC action on issuance of licenses. The situation has deteriorated to the point where the NRC licensing process appears to have become almost completely open-ended and that the NRC is incapable of making timely decisions. This situation demands immediate correction.

Breeder Reactor Systems - Breeder reactors continue to represent the best apparent technology to satisfy the long-term need of assured electricity supply that can be available for many centuries. Earlier projections of when this technology would be needed were overly optimistic and there is time to pursue the important matters that will permit this technology to be used efficiently. Now that Congress has withdrawn support for the

Clinch River Breeder Reactor demonstration project, the DOE breeder program should be directed toward those research and development programs that have the greatest potential payoff. Funds should be made available and concentrated on those tasks that will expand our technological base on breeder reactors and the accompanying fuel cycle.

Convertor Reactor Systems - Light-water reactors being used successfully to produce electricity are converter reactors. The continued use of these reactors is vital to the financial health of the nation. Programs are needed to overcome the unnecessarily burdensome institutional, financial, technical, and regulatory barriers in this area. Also, many utilities continue to support the High Temperature Gas Reactor (HTGR) concept and believe that it should be pursued as a reasonable alternative technology to today's light-water reactors. These utilities support the development of HTGR technology both financially and with managerial expertise through the Gas Cooled Reactor Associates (GCRA). Continued Government cooperation and financial support are vital to the success of the joint effort now underway to determine if the HTGR will be sufficiently attractive to achieve commercial acceptability.

* * *

Senator DOMENICI. Thank you very much, Fred.

Fred, you're aware of with reference to at the last meeting we discussed the need to have GAO involved in the auditing and accounting in the program that you described as the largest civil works program.

Mr. WEBBER. Yes, sir.

Senator DOMENICI. We sent that letter off. If it is of interest to you, we would be glad to share the letter with you.

Mr. WEBBER. We would be delighted to have that letter.

Senator DOMENICI. I'm not sure what the response is going to be yet, but DOE didn't seem to have any objection, although they thought there was plenty of auditing and bookkeeping and accounting going on. We sent that in any event.

Senator Evans, what I have done, unless you're in need of some change, which I would be glad to accommodate, I thought we would finish, take Mr. Berick and then ask questions. We will have all three before us.

Senator EVANS. Sure.

Senator DOMENICI. You may proceed. Thank you for coming.

STATEMENT OF DAVID BERICK, DIRECTOR, NUCLEAR WASTE PROJECT, ENVIRONMENTAL POLICY INSTITUTE

Mr. BERICK. Thank you, Mr. Chairman. I will briefly summarize my testimony. It only concerns the Department's high-level nuclear waste program.

As you know, Senator, Mr. Chairman, the Department has now been at the process of implementing a Nuclear Waste Policy Act for a little over a year. They have made some significant progress. They have got the fund in place, they have signed contracts, they have created the office, and even without a permanent director, we have noticed a significant change in the way the waste program is run as a result of that independent office.

But I think it's pretty obvious to all of us that they are being hampered by a number of factors, some of which have to do with the fact that there's a previous program already in place that is now in the process of being molded and shaped to fit the new requirements of the Waste Policy Act.

But we are also somewhat concerned about the fact that the program is highly decentralized, involving five operations offices. And when you get into situations, for example, the question you raised at the last hearing about negotiation with State relations, it's the regional operations offices that have the primary responsibility for the negotiations, but everything has to be cleared back through headquarters.

So you have this sort of intermittent exchange that sometimes takes a lot longer to get to a very simple agreements that it probably ought to.

We also believe that there's a serious problem inherent in the Waste Policy Act itself, and that's the problem of the fact that there are sets of procedures in the act that the Department is required to follow, and there are also deadline, schedules. And it doesn't appear to us at this juncture, and I think it's something the Department is concluding also, that you can't fulfill all of those procedures within the deadlines. And it's something that I want to turn to at a little bit later point in my summary, but I think it's something that is dramatically skewing the program, and I think it's something that Congress may want to clarify for the Agency.

My testimony details five areas where we think the Department's program is running into trouble, and may be running into serious trouble, and may be running into serious trouble and it may get derailed.

First is on the sight selection process. DOE is locking itself into a pool of nine sites, from which they are required by the act to pick five.

Now, there's nothing wrong in and of itself with that kind of approach, if you have a high degree of confidence that those sites that you're starting with are adequate sites.

Our concern, and the concern of many of the States has been that we don't have the degree of confidence in the Department's sight selection program and the Department's sight selection guidelines and the process to really be assured that what we're starting with in the initial pool is going to get us through the end of the process.

Second, I think it's important to spend a little bit of thinking about the sight selection guidelines themselves.

The NRC, earlier this year, issued a determination saying that they could not oncur in the guidelines unless the Department altered them in seven specific ways.

There have been a round of negotiations in four separate meetings between the NRC and the DOE and there has been significant progress made.

We don't have closure yet on the Department meeting those agreements, but I think it's important to recognize that the NRC has stepped in where the DOE refused to go, which was to attempt, at this early stage, to get a set of ground rules on the table that would get us a set of sites that we would have a ligh degree of confidence in.

The second issue is the mission plan. Again, the Department of Energy is locking itself into a mission planning process, a respository development process, aimed at getting a repository on line by January 31, 1998.

There's nothing wrong with that, again, in and of itself. That's the date that the Congress set as a target in the end.

The question is, is that skewing the planning process? And we believe that it is. The Department, in its draft mission plan, released in December, indicates that it cannot meet that date without exercising some fairly significant assumptions.

What we would hope for is the Department would lay out a repository schedule all the way through. We can come back and see if we can shave time off in order to meet that target date.

But I think the important thing at this juncture where we are not in the program is to get all the cards on the table, get the whole program laid out and then come back and see whether or not we can cut some corners on the time.

The fixation with the January 31, 1998, date—just to give you an example of the kinds of things that it's driving the Department to consider, is that as of last week at a meeting with the salt States—

the States with salt deposits that DOE is exploring, DOE discussed a proposal to drill a second shaft, the second fullsized shaft during the characterization stage at a cost of $25 to $30 million at a minimum, simply to begin to get construction started at the site.

So we would be spending that money at those sites; two of which may never be selected for repository. The States, understandably, are upset with the idea that DOE would be starting construction of a repository and committing those additional resources absent final selection of that site.

So we're undermining our political credibility of the program. We are potentially spending $90, $100 million up front that we might not want to spend in an effort to demonstrate that we can meet a date that might be realistic to start with.

Third, and an issue that is of great concern to this committee, I know, is the monitored retrievable storage program.

DOE has proposed in the mission plan to accept spent fuel beginning January 31, 1998, whether or not a repository is in operation.

The Department proposed that it could use monitored retrievable storage as a means of beginning to accept that spent fuel in the interim.

The question we have, sir, is whether or not that is not an interim storage facility; that that is not an away-from-reactor storage facility. It's not our reading that that was the kind of mission that was intended for monitored retrievable storage.

We believe that is it in conflict with the act. We do have concerns about monitored retrievable storage, about the way it will be sited, the way it will be funded, especially when you're looking at a waste fund that's designed for a close-in system, and MRS is going to be an open-end system.

But most important, and again the kind of thing that I think this committee should give some direction on is, what is the trigger for monitored retrievable storage, what is it in the repository program, what failure, what shortcoming, what deadline missed, or site not selected triggers the decision to drop the repository program and proceed with MRS?

As you know, the act requires the Department to submit a development plan July 1985. But the question the Department is now grappling with, and will resolve probably in the next couple of months in the mission plan, is what it perceives the trigger to be.

I think that's a significant issue, because I think it will shape a lot of the debate about how monitored retrievable storage is developed and perhaps authorized in the next Congress when that report comes up.

Fourth is the question of the Department's decision in January to reorganize the Nuclear Waste Program, and to roll the uranium enrichment management activities into that office.

We think that's a bad idea. We think it's in conflict with the Nuclear Waste Policy Act's intention that a separate office with an independent and exclusive responsibility for waste be created.

We think that the proposal to reorganize is going to simply detract from the management of both programs, something that neither program can afford at this point.

Fifth and last, is the question of revenues. We believe that the Department is seriously underestimating the revenue flow—I'm sorry, overestimating the revenue flow from the program.

As of last July, they believed that the 1 mill per kilowatt hour fee would be adequate. With the budget document submitted with the fiscal year 1985 budget, they're already projecting a shortfall of some $78 million by fiscal year 1987.

Not that that's an extreme number, it can be made up. But the important thing I think to look at is the trend. Revenues are based upon kilowatt hours generated. The DOE numbers in the budget submission for fiscal year 1985 were based on a 130 gigawatt mid-case projection by the Energy Information Agency.

I think it's fair to say right now, and using the Atomic Industrial Forum's numbers, there's only 115 or 116 gigawatts in the pipeline right now. To say that we should base our revenue projections and the fees to be collected on the plants that will not be coming online in the foreseeable future and are not even ordered in some cases, I think skews the kind of decisions that may be getting made down at the Department.

So just in summary, I think that the revenue flow and the Department's projections on revenues and costs really need to be given a very, very close look.

Just on the cost side, transportation is estimated by the Department to be 30 percent of the overall program cost for disposal. We don't know where the repository is right now, so we don't know what the transportation distances are going to be, and, therefore, we don't know what transportation costs are going to be.

The Department's costs have a great degree of uncertainty in it. And I think that's all the more reason why the revenue projections and costing of this program really needs to given careful scrutiny.

Thank you, Mr. Chairman. This concludes my testimony.

[The prepared statement of Mr. Berick follows:]

ENVIRONMENTAL POLICY INSTITUTE

STATEMENT OF DAVID BERICK
ENVIRONMENTAL POLICY INSTITUTE

BEFORE

THE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

CONCERNING

DEPARTMENT OF ENERGY HIGH-LEVEL NUCLEAR WASTE PROGRAM

April 5, 1984

Mr. Chairman and Members of the Committee thank you for the opportunity to testify on the Department of Energy's high-level nuclear waste program.

Mr. Chairman, a little over fourteen months ago the Nuclear Waste Policy Act(NWPA) was signed into law. Since then the DOE has been faced with the difficult task of interpreting the Act and reconciling the DOE nuclear waste program which existed at the time of enactment with the new requirements of the Act.

It is, and has been, our view that the procedural requirements of the Act and the deadlines contained in it are irreconcilable. DOE can simply not carry out the required steps in a technically and politically credible manner within the NWPA timeframe. DOE, to its credit, has publicly acknowledged the difficulty of meeting the deadlines and has taken the bold step of stating publicly on a number of occasions that certain deadlines will simply not be met. For example, DOE will not meet the March 1987 date for recommendation of the first repository site and now projects an October 1990 date.

These DOE statements, unfortunately, have often been greeted by much hand-wringing from some nuclear industry spokesmen. These anxieties seem, in turn, to have had the desired effect of locking DOE into the last "official" milestone of January 31, 1998. As is clear from reading the DOE Draft Mission Plan, however, this final January , 1998 deadline is no more realistic than any other. In fact, it can be met only through a series of program assumptions requiring unique interpretations of the NWPA and NRC and state participation.

As I will discuss in a moment, holding to the Draft Mission Plan and its 1998 commitment to take spent fuel may force the abandonment of the NWPA waste program and may also result in the re-writing the NWPA in the 99th Congress.

IMPLEMENTATION PROBLEMS

There should be no mistake about the difficulty of refashioning Federal nuclear waste policy and restructuring the DOE program to comply with the conflicting mandates of procedures and deadlines in the Act. DOE has met some significant milestones including the establishment of the Nuclear Waste Fund and completion of contracts with utilities. Although a permanent director has not been appointed, the Office of Civilian Radioactive Waste Management has been established and that Office is attempting to gain control over the highly decentralized program in place prior to the Act. The current program managers have come a long way toward overcoming the "horse race" approach among different DOE operations offices and contractors interested in promoting "their" repository sites.

The DOE still has a long way to go in many of these areas and the Draft Mission Plan contains some disquieting references to maintaining the prevailing "decentralized" management structure of the high-level waste program. Of even more serious concern are a series of extremely perilous policies announced or proposed in the past few months.

SITE SELECTION

First, DOE is betting that the nine sites already identified --seven salt sites, Hanford basalt, and Nevada tuff--provide an adequate universe of sites from which to select and license the first repository. DOE states in both the proposed Site Selection Guidelines and the Draft Mission Plan that the site screening process for the first repository is closed. Inspite of a complete absence of supporting language or legislative history, DOE has stated that it reaches this conclusion, in part, because the NWPA ratified all siting decision predating enactment(see Guideline 960.3-2, Guideline 960.3-2-1, draft DOE analysis and comment response document @ p. 13). DOE appears to have adopted its unflappable commitment to these nine sites based on the difficulty in meeting the NWPA schedule for the first repository if additional sites were required.

DOE is, however, hedging its bet on these nine sites by proposing the lowest possible threshold for selection at each step. For example, DOE proposes in the Site Selection Guidelines to nominate sites based upon "available data." In our view, DOE could and should collect sufficient data on hydrologic, geochemical, and rock characteristics through borehole drilling programs and other field investigations to justify nomination. DOE instead is postponing much of this preliminary field work to the site characterization stage and will therefore conduct it only after it decides on the final three sites.

As the Committee is no doubt aware, the NRC has issued a preliminary determination that it will not concur in the DOE's site selection guidelines under Sec. 112 of the NWPA unless seven conditions are met. Although the NRC determination does not answer all of the concerns raised by representatives of states, Indian tribes, and environmental and citizen organizations it does represent an important opportunity to improve the site selection quidelines; guidelines upon which the success or failure of the site selection process rests. Central to the public concerns is the fact that the guidelines are being applied retroactively, in the case of the first repository, to a set of sites previously selected without benefit of those guidelines.

As is painfully obvious to those of us who have followed the DOE guidelines development process for more than a year, DOE has not adequately addressed either the technical concerns over how it conducts its forthcoming site selection process nor the public confidence aspects of that process. Although many argue that institutional constraints are delaying the development of waste repositories and not technical problems, the inability or unwillingness of the DOE to respond to criticisms of its development of the quidelines indicates that DOE is unable to recognize and address the "institutional problem".

The NRC should be commended for recognizing the importance of the site selection quidelines and for stepping in to assure that they addressed both the need for a technically conservative site selection process and public confidence.

MISSION PLAN

Second, the DOE is committing itself, as shown by the Draft Mission Plan, to an entirely counterproductive planning process. While recognizing that the January 1998 date can only be achieved by making "significant assumptions", the Mission Plan nonetheless concludes that Department is committed to that date.

Rather than the detailed and defensible analysis of technical and procedural tasks necessary to assure that repository development problems can be overcome, DOE simply takes the contrary approach. DOE sets January 31, 1998 as its target date and, with only minimal analysis of their probability of occurring, quite simply assumes that there will be no siting delays, no litigation, no construction delays, no labor strikes, and no land acquisition problems, to name a few.

In addition to the "assumptions" mentioned above, DOE also assumes:

* There will be no delays in obtaining any state permits,
* In-situ testing can be done in less than 27 months for the "worst case" site despite evidence it could require 40,
* NRC will allow construction of the repository to begin while the construction permit is being considered.
* Its statutory interpretations, including that of Sec. 114(f) governing NEPA alternatives, are not challenged. DOE states that if its interpretation of Sec. 114(f) is successfully challenged at the EIS stage, it may be required to characterize an additional site thereby adding three to four years to the schedule.

DOE further cripples its planning process and the utility of the Mission Plan by declaring that the primary goal of the Mission Plan is to begin to accept spent fuel and high-level waste January 31, 1998 whether or not a reposistory is available.

We believe that this goal is contrary to the NWPA which makes the primary mission for DOE and the Mission Plan the establishment of geologic repositories in a timely manner. It is our reading of the NWPA that Sec. 302 authorizes DOE to enter into contracts with generators or owners of spent fuel for the "acceptance of title, subsequent transportation, and disposal of spent fuel." However, Sec. 302(a)(5) clearly states that DOE may not accept spent fuel until after commencement of repository operation.

It is our reading of the NWPA that Congress did not intend to authorize DOE to accept spent fuel of high-level waste "whether or not repository was available," but rather intended January 31, 1998 as the target date for repository operation. We do not believe that Congress intended DOE to be responsible for the tens of thousands of metric tons of spent fuel owned by utilities as of that date.

By setting the January 31, 1998 date as the focus for the entire repository planning process, DOE is forced to let the end point drive its decision process rather than a direct, technically defensible schedule.

DOE's planning process is also hampered by its failure to address major programmatic questions such as the decision to commingle defense program and commercial wastes pursuant to Sec. 8 of the NWPA. Although Sec. 8 clearly contemplates the option of commingling the two waste streams, the December Draft Mission Plan entirely skirts the question except to suggest that disposal of defense waste will in no way interfere with the acceptance of commercial waste. We question whether DOE will be able to satisfy its defense program obligations, including NEPA requirements, by adopting a "no interference" policy.

MRS DESIGNATED FOR FEDERAL INTERIM STORAGE

Third, DOE has proposed an open-ended commitment to provide spent fuel storage for nuclear powerplants beginning January 31, 1998 by developing Monitored Retrievable Storage(MRS). DOE intends to begin to accepting this waste on a fixed schedule whether or not a repository exists or could reasonably be expected to accept spent fuel at the proposed rate even if it did exist. DOE plans to accept 9000 metric tons of waste or spent fuel within the first three years of this date; an amount roughly equal to all of the spent fuel now in storage. It also proposes to accept and transport this spent fuel at an entirely unprecedented rate requiring an inordinate resource commitment.

DOE's intention to provide storage services beginning in 1998 is contrary to the intent of the Nuclear Waste Policy Act. DOE proposes to provide interim spent fuel storage, which is otherwise severely restricted by the Act, by means of Monitored Retrievable Storage(MRS). I believe that the definition in the NWPA of MRS defines MRS as an alternative to geologic repositories. It does not constitute a means for circumventing the limits on Federal storage contained in the NWPA.

We continue to have reservations about the MRS as defined in the NWPA. The definition contained in Subtitle C does not spell out the performance requirements for MRS facilities such as the actual period of time an MRS facility is expected to function. In addition, the siting process for MRS and the role of states and Indian tribes in that process is not clear. It is also not clear how the long-term monitoring and maintenance costs would be financed since the waste fund is modeled on a closed-end system.

The most important unresolved issue concerning MRS, however, is how the decisions to authorize and construct an MRS would be made. What failure in the repository program or delay in the schedule would trigger construction? The NWPA gives little guidance on this issue except to instruct DOE to study the question. Unfortunately, DOE's Mission Plan proposal to provide an unlimited storage capacity in the absence of any realistic ability to have a repository operational by January 31, 1998 will lead DOE and some segments of the industry to conclude that MRS is "needed" and should be developed well in advance of any demonstrable "failure" of the repository program.

If one assumes the Draft Mission Plan estimate of eight to eleven years to place MRS in operation, submission of the MRS proposal in July of 1985 would require almost immediate authorization in order to fulfill the DOE's proposed 1998 commitment. The Mission Plan virtually guarantees that DOE will recommend MRS at that the eleven year lead-time mark, or January 1987; three-and-three-quarter years before it now plans to recommend a final repository site.

REORGANIZATION OF ENRICHMENT AND WASTE PROGRAMS

Fourth, in mid-January DOE announced a decision to reorganize the DOE and to assign management responsibilities for the uranium enrichment program to the Director of the Office of Civilian Radioactive Waste Management. This position has yet to be filled by a permanent director let alone a director who must assume the burdens of the collapsing uranium enrichment operation. In our view, the Nuclear Waste Policy Act correctly provided for the creation of an independent nuclear waste office to assure both the highest level of management attention and to insulate the nuclear waste mission from the Department's "promotional" responsibilities for nuclear energy and its nuclear weapons activities. The proposed reorganization is a major step backward from this mandate.

REVENUE SHORTFALLS

Fifth, there is a growing question over the fiscal integrity of the nuclear waste fund. This is an expensive program. DOE estimates that the disposal program now being planned will cost between $18 billion and $20 billion in FY 1982 dollars. Anticipating a 3% inflation rate, DOE projected program costs in a report released last July(DOE/S-0020/1) of between $35 billion and $64 billion. A 5% inflation rate would increase total program costs to the $61 billion to $114 billion range.

These cost estimates are truly "ball park" estimates. Final conceptual designs for a basalt-based repository will not be completed until FY'85. Preliminary capital cost estimates for a salt-based repository will also not be completed until FY'85 and according to the DOE budget document, a salt-based final conceptual design will not be completed until FY'88. Similarly, we do not know where the repository will be located and consequently we do not know what actual transportation distances and costs will be. DOE estimates that transporation costs will comprise almost one-third of total program costs.

On the revenue side, the future of the Waste Fund is also in some doubt. The DOE budget document anticipates a shortfall of funds in FY '87 of some $78.8 million. Consequently, DOE is "considering" an increase in the waste disposal fee above the 1.0 mil-per-kilowatt-hour set in the Nuclear Waste Policy Act. We note in passing that as recently as July, DOE anticipated that the one mil level would be adequate to finance the program.

The DOE budget document also anticipates that beyond the FY'85 and FY'86 fee increase that future fees will increase at the rate of inflation. Although the document does not state what assumption it makes for the inflation rate, that is less important than a the recognition that the fee must be adjusted annually for inflation.

I do not think that DOE is being conservative enough in its projections of revenues. Although the DOE has revised downward its projections since July and is working diligently to establish a more accurate method for projecting revenues and costs, the truth of the matter is that DOE is facing a declining fee base as a result of the cancelation and delay of nuclear powerplants. Whereas the DOE used a mid-range case of 165 GWe installed capacity in the year 2000 for its July estimate, this estimate is now recognized as exceedingly high. There are only 115 to 116

GWe of capacity now in the pipeline, that is plants in operation or underconstruction. The Atomic Industrial Forum recently identified a total "on-order" capacity of 2,240 MWe. These numbers will not increase, and in our view, they will continue to decrease through additional plant cancelations, such as the recent Zimmer and Marble Hill announcements. They will also decrease as a result of plant retirements.

Since revenues are based on kilowatt-hours generated, additional consideration must be given to operational or regulation related decreases in generation either on a plant-by-plant basis or by reactor-type.

DOE recognizes that declining plant capacity will increase its financing problems because of a smaller fee base and because it would take longer to fill the first repository thereby stretching out its operating costs. The July DOE report, however, identified these problems occuring in a low-range case of 120-130 GWe for the year 2000. As noted above, this low-range is, in our view, an optimistic projection.

The funding shortfalls are not insurmountable. They can be corrected through fee increases and management strategies including the prompt inclusion of defense program wastes in a joint disposal program. They can also be addressed through technical programs such as the development of extended burn-up fuels which will reduce waste volumes and overall program costs. What should be recognized, however, is that there is a clear need for increasing revenues beyond the one mil level set in the Act.

CONCLUSION

DOE, at this juncture, is creating more uncertainty and more obstacles to completion of its nuclear waste program than it is resolving by keying its repository program to the January 31, 1998 date. It proposes a costly open-ended commitment for spent fuel storage inspite of projected budget shortfalls and statutory directives to the contrary. It has decided upon questionable interpretations of the Nuclear Waste Policy Act which threaten both the near and long-term goals of the program. It has proposed a Mission Plan that circumvents the questions it was intended to address. It has created great confusion and antagonism toward its site selection program by failing to address state and public requests for a technically conservative approach especially in developing its site selection guidelines.

We believe that if these policies are not reversed, we will find the next Congress redebating the entire set of issues thought to have been resolved in the NWPA.

Thank you. This concludes my statement.

Senator DOMENICI. Thank you very much.

Senator Evans, you care to proceed?

Senator EVANS. Mr. Chairman, I was a few minutes late and didn't have an opportunity to listen to the first set of testimony.

Let me start with Mr. Webber. I'm concerned about the financing of our Nuclear Waste Program and the adequacy of the current charges being made.

Do you have any current information on how many nuclear plants are currently under construction or have been started, and how many of those are now continuing in construction as opposed to those which have been mothballed, stopped, canceled, or otherwise not under construction any more?

Mr. WEBBER. We have approximately—well, we have exactly right now 76 nuclear reactors in commercial operation, 6 others in the start-up phase, and we have 41 units that have construction permits with scheduled completion dates. I think that's the best answer I can give you.

Now, to make a prediction as to whether or not all 41 will be completed, I am not going to do that.

Senator EVANS. Well, I'm not asking you that. That wasn't the question. The question was how many are actually under construction. I suppose that would be 41 units.

Mr. WEBBER. That's 41. Yes, sir.

Senator EVANS. How many of them currently are continuing construction, and how many are currently stopped?

Mr. WEBBER. I'm told that of the approximately 41 that are under construction, 35 are still under construction. In other words, the remaining six in the construction program have stopped.

Senator EVANS. Are you telling me that there are only six plants where construction has been started that are now—I can name more than six just without half trying.

Mr. WEBBER. We have almost a dozen, Senator, that are indefinitely delayed and are not included in the total of 41. So you could add those to the list, and you've got approximately 18 where the construction has stopped, the project has been indefinitely delayed.

But when I got these numbers together and listed the 41 units that had construction permits with scheduled completion dates, since that time 6 have ceased construction.

Senator EVANS. I have asked this question of others, too, and am having great trouble getting accurate answers.

Can you, through Edison, get to us a definitive list of those for which there have been—I guess the best measure of whether you start or not is whether construction permits have been issued?

Mr. WEBBER. Yes, sir.

Senator EVANS. But you said there were 42, and then you left the other 15 out. What I'd like is a specific list of all of those for which the construction permits have been issued and where each one is now in terms of continued construction versus those which have been stopped, delayed, or for whatever reason.

Mr. WEBBER. We can have that by this afternoon. But, again, the round number would be 76 in operation, 6 that are in startup, 42 had construction permits with scheduled completion dates—that's really down now to about 35, with 6 experiencing construction delays, and about another dozen have been postponed.

Senator **Domenici**. Excuse me. Senator.

Of that dozen, they had construction permits, is that correct?

Mr. **Webber**. Correct.

Senator **Evans**. That was in addition to the 41, or is that part of the 41?

Senator **Domenici**. It's in addition to.

Mr. **Webber**. In addition to the 41.

Senator **Evans**. So as I understand what you're saying is that there were 53 where construction permits had been issued, 18 of which are now postponed, stopped, or otherwise not going on?

Mr. **Webber**. That's approximately correct, yes, sir.

Senator **Domenici**. Can you supply better information than that, deetails, names?

Mr. **Webber**. We will break it down by name, detail, date, unit number, et cetera.

Senator **Domenici**. I think maybe, Senator, we could also, if you desire, have the staff propose in behalf of the subcommittee an inquiry of the NRC along the lines that you have just requested and let them give us a detailed response.

Mr. Webber, would the NRC have some estimate of how much was invested when the stoppage occurred? I think that is kind of important.

Senator **Evans**. That would be helpful, too.

Mr. **Webber**. Yes, sir.

Senator **Domenici**. The NRC would have that, would they not, or would they?

Mr. **Webber**. When you say invested, you mean dollar amounts?

Senator **Domenici**. I'm sure our new Senator is saying to us, we see that this one had 4 billion committed and it's no longer going to be built; that one has a half billion in it—that's what you want, isn't it?

Senator **Evans**. Well, the difficulty in really making a determination as to, for instance, whether the current charges are going to be sufficient for waste disposal sites. We have got to have a clearer idea, and I'm having difficulty getting that idea of where we are, how much is postponed, how much is likely to even be completed. And that may be a more difficult task than you want to take on.

Mr. **Webber**. That is going to be extremely difficult, sir.

Senator **Evans**. I'm not suggesting that we do that. But at least knowing where we are gives us some chance to better decide whether we are adequate in terms of our current charges and whether they'll come close to meeting the needs when we have those needs for waste disposal sites.

Senator **Domenici**. Why don't we do this in addition, Senator. Would the staff compose a letter to the appropriate official within the Department of Energy and ask them to give us an explanation in detail as to how they have arrived at the estimates in terms of the revenues that they expect to receive into the Waste Program. And then we can match that up with facts and——

Senator **Evans**. Indeed, because they obviously have to determine that through some expectation of plants coming on line, when they come on line, and how much energy they're going to produce so they can use the millage rates to determine their revenues.

On page 7 of your testimony you said, "We have observed pressures being applied on DOE to achieve preferences within its sight selection guidelines for certain potential host States to gain an advantage they were unable to gain from Congress." I guess I'm not quite sure what that means, but perhaps you could explain a little further.

Mr. **Webber**. I'm reminded that certain States have asked for detailed disqualifying features in the guideline area. So that that does put that kind of pressure on the program, and the result being that we have had a delay in the issuance of guidelines, and that's what concerns us.

Senator **Evans**. Well, in just reading what you have said here, it sounded to me like there were certain potential host States to gain an advantage, sounds like they were hellbent to beat each other over the head to be the site selection. But now you're saying it's just the opposite.

Mr. **Webber**. I should have been more precise in my phraseology. Yes, sir.

Senator **Evans**. Well, it sounded a little—I'm not aware of any State that's standing out in front hollering and shouting for one of these things.

Mr. **Webber**. I'm not either.

Senator **Evans**. OK. On page 9 you start talking about revenues and the one mill per kilowatthour fee.

You're saying we need considerably more supporting justification before an increase is permitted. Do you have any indication that considerably more supporting justification that the current amount is going to be sufficient?

Mr. **Webber**. Not yet. We have to factor in the cancellations and the delays.

Senator **Evans**. Has anybody attempted to do that yet?

Mr. **Webber**. Not to my knowledge. But there's such a disparity. We're dealing in billions of dollars, and I think between $15 to $25 billion, that it's pretty hard to get your arms around it, and it's pretty hard to get that precise.

In fact, when we send that data up this afternoon that you have requested, I would submit to you that it's going to be pretty impossible to determine as to whether or not the funding in the final analysis is going to be adequate.

But we don't think that this is the time to up the kilowatthour charge. We don't think we're there yet. We're not sure we'll ever get there, and that's why what we say here on page 9 we think is accurate.

Senator **Evans**. If you say you're not sure you'll ever get there, that presumes then that you will never make a determination that there ought to be an increase and——

Mr. **Webber**. Well, I think that we'll be able somewhere down the road to make a determination as to what is going to be adequate. And when we do, then we can come back with some more precise recommendations, but right now we think it would be premature to up the kilowatthour fee.

Senator **Evans**. How do you feel about the timeframes that are being set forth for development of waste disposal sites and their readiness for accepting nuclear wastes in the 1998 timeframe?

Mr. **Webber**. Well, we have got to live by that 1998 timeframe. That's why we're concerned about DOE being so caught up in the process, and we're urging them on a regular basis from the highest levels on down to get on with it, because we feel that we're going to need that repository by 1998. That's the one we really have to stick to.

Now, we have been assured by DOE that they recognize that, too, and are going to move accordingly.

Senator **Evans**. Well, what in your view would happen if, for whatever reasons, that 1998 timeframe were not met?

Mr. **Webber**. Well, some utilities have told us that we would be in the position of shutting down units if that were the case.

I'm not going to sit here and make a difference definitive statement along those lines. But for planning purposes, a utility has got to know and be assured today that in fact that repository is going to be there. Otherwise, all kinds of different planning has to take place, and contingency plans have to take place. And it will put the whole MRS concept in a different perspective if, in fact, somebody says that we're not going to make the 1998 deadline.

We have, again 76 nuclear units running. We're going to have many more running in the next few years, we hope. We hope they'll be critical. And that 1998 date is very important to us.

Senator **Evans**. This was not—at least I don't remember reading anything in your testimony that relates to another cost of nuclear plants—and I don't know how much work has been done on the decommissioning costs of a plant. Once you reach the end of its useful life and decide to decommission, to what degree are those costs now being recognized in the cost of electricity from those plants?

Mr. **Webber**. That's difficult one to answer, Senator Evans. There is a cost associated with decommissioning nuclear powerplants. The utilities themselves want to plan for that.

We're working with the tax committees now to make sure we're not penalized for setting up escrow moneys for decommissioning costs and things.

Senator **Evans**. No, and I don't think you should be.

Mr. **Webber**. And how it's factored into the cost of the plant itself I'm just not prepared to say, but I could get that for you. I'm not an expert in that particular area.

Senator **Evans**. Do you believe that it now is being factored in, or that it is not adequately being factored in?

Mr. **Webber**. Well it is, as much as it is pointed out here that the PUC's will allow us.

Dick, have you had any experience yet on the decomissioning question?

Mr. **Walker**. It depends on your local State public utilities commission and your rate structure. And, certainly, in our State we're allowed to collect an amount. Now, whether by the year 2010 that will be adequate or not—but I think most jurisdictions do recognize that and allow you to collect some to be put aside for the decomissioning.

Mr. **Webber**. The real question is how it's going to be treated taxwise.

Mr. **Walker**. Yeah, taxwise.

Senator **Evans**. Could you get for us examples of where you think that is now being recognized in the most appropriate way, and how much that is, and how much the expectations are for the cost of decommissioning?

This follows along the line of questioning I'm going to continue on with a whole host of witnesses until I either wear myself out or get to what I think is an important consideration; and that is, to ensure that we are putting the direct costs, and assigning direct costs to every source of electric energy. In the case of nuclear, it's the waste depository, which is the cost of producing energy, it's the decommissioning costs, which are the costs of producing energy. When we turn to coal, it must include, you know, to the degree that we can accurately identify, the penalties of acid rain. That's got to be included as the cost of producing that kind of energy.

I do not believe that we are adequately recognizing the different costs of producing electric energy, and, as such, we may be getting, or giving inaccurate signals as to which form of energy is really the most economic and where we ought to put our major efforts.

Mr. **Webber**. Well, as far as the decommissioning numbers are concerned, we will abide by your request, and I think we can do it. I think we can show you good examples of how the decommissioning costs are factored in State by State.

Senator **Evans**. I've just got one further question. In your testimony on page 17 you talk about the gas centrifuge enrichment project, suggesting that it be continued at a reduced level until a better understanding is provided on the actual contract situation, and then an opportunity provided for the review of the technology choices from proved efficiency.

Would you elaborate a little on that. Where are we on the gas centrifuge and what appear to be the problems?

Mr. **Webber**. I'd like to call on our vice president for nuclear, who is well versed in this particular area, Larry Mills.

Senator **Evans**. Surely.

Mr. **Mills**. Yes. We are very much in need of economic capability of producing enriched uranium. The process that we have been using for the last several decades, the fusion process, consumes a great amount of electricity and it, as a technology, is not satisfactory in containing the future costs. They will rise, unless we proceed with some other technology.

That was one of the main motives for going forward with the gas centrifuge plant, was to provide the techology with lower cost.

Senator **Evans**. I'm familiar with the gas centrifuge process.

Mr. **Mills**. The question that is before DOE at this point is, is there an advanced capability, advanced technology that would be preferred with going forward with the present Set 3 machines that they have planted for the Gee-sept. They expect to have sufficient data so that a year from now, March 1985, they should be able to make the decision whether to proceed with an advanced centrifuge or convert to the technology of the laser enrichment.

We believe it's appropriate to maintain the gas centrifuge as presently conceived, the Set 3, at the reduced rate that they have planned, while they collect the information to make that determination next year. And we believe that next year is the appropriate time to make that determination.

Senator EVANS. Do you have a brief description of these two new technologies, your laser and your advanced gas centrifuge, that you could provide to me just for my own information?

Mr. MILLS. Yes. We would provide that. It would be Department of Energy information.

Senator EVANS. Well, maybe, Mr. Chairman, from wherever we would best get it, it would be of interest to me at least to have that information.

Senator DOMENICI. We'll do that.

[Subsequent to the hearing, Mr. Webber supplied the following information:]

FREDERICK L. WEBBER, Executive Vice President

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April 27, 1984

The Honorable Daniel Evans
United States Senate
Washington, D.C. 20510

Dear Senator Evans:

At the April 5 Subcommittee on Energy Research and Development hearing on the DOE Fiscal Year 1985 Budget Request, you expressed concerns about the financing of the nuclear waste program and the adequacy of the current fee. Enclosed, per your request, are (1) the current status of nuclear plants and (2) my responses to your questions concerning nuclear decommissioning.

We share your concerns about the cost of the nuclear waste program. Our industry will continue to work with the Congress and the Administration to assure that the money collected is being spent effectively and efficiently. We feel, however, that considerably more justification is needed before an increase in the fee is permitted.

If you have additional questions, please let us know.

Sincerely yours,

Fred Webber

Frederick L. Webber

FLW:jms
Enclosures

Responses to Questions by Senator Evans
During the Senate Hearing on April 5, 1984

Question: What is the current commitment to nuclear power plants by domestic utilities that should be included in the revenue calculations for the Nuclear Waste Fund to support the DOE program on nuclear waste disposal? How many nuclear plants are actively under construction? What plants have been cancelled recently? Is the revenue sufficient to fund the waste program?

Answer: Enclosed are five tables that indicate the current status of nuclear plants and recently announced terminations and cancellations. Table I lists the 78 nuclear plants that are now in commercial operation. This includes 2 units, McGuire 2 and San Onofre 3, that achieved commercial status on April 1, 1984. Table II identifies 9 additional plants that include 2 plants with full power operating licenses that should achieve commercial status soon, 3 plants with operating licenses but currently shut down, 3 plants with fuel-load or low power operating licenses, and the Hanford N reactor that is providing electricity as a DOE plant, not licensed by the NRC. Table III lists 40 plants with construction permits that have a scheduled date for construction completion. Of these 40 plants, 35 plants are actively under construction and 5 plants have halted construction temporarily or are pursuing only a minimum construction effort. Table IV lists 7 nuclear plants that hold construction permits but whose construction has been indefinitely delayed. Table V lists 30 nuclear plants on which terminations have been announced or cancellations have occurred during calendar years 1982, 1983 and 1984.

Thus, the current relatively firm commitment for domestic nuclear plants includes a total of 125 plants with an electrical generation capacity of about 113 GWe. Based on conservative estimates of the amount of electricity that will be generated during the life of these nuclear plants, revenues to the Nuclear Waste Fund from the 1 mill per kilowatt hour fee will be about $20 billion. This is essentially equivalent to the overall cost estimate for the waste program. Therefore, the current fee appears to be adequate at this time. As called for in the legislation, the program is to achieve full cost recovery over its life and the fee is to be determined on that basis. We believe that any change in the fee should be based on substantial supporting justification by DOE before it is recommended and approved.

Question: Are the future costs for decommissioning of nuclear power plants included as a component of the current cost of nuclear energy? How is this achieved and what is the most recent estimate for the cost of decommissioning?

Answer: It is well understood by the electric utility industry that after a nuclear power plant has served out its useful life it will, in some form, be decommissioned. Furthermore, it is an accepted concept that those benefitting from the use of a particular nuclear power plant should be charged for decommissioning the plant, as they are charged for constructing and operating the plant. Almost every state served by operating nuclear power plants allows decommission funding in rates. Those few that do not are considering the question. The Federal Energy Regulatory Commission also allows decommissioning costs to be included in rates.

There are three major funding methods:

- External fund managed by a trustee
- Internal funding managed by the utility, but invested outside the company
- Negative salvage depreciation, where funds are collected through depreciation charges, used for general corporate purposes and reduce the rate base

While EEI prefers the negative salvage depreciation method, the other two are certainly acceptable. The choice of method depends upon the particular state (or FERC), utility involved, etc.

The cost of decommissioning a nuclear power plant will vary depending upon a number of factors, including the type and size of reactor, decommissioning alternative selected (which would depend on the intended future use of the site), and Nuclear Regulatory Commission regulations applicable at the time of decommissioning (which are currently undergoing revision).

Keeping in mind these factors, and based on today's NRC regulations, the range of decommissioning cost estimates vary from $50 to $165 million dollars (January 1, 1984 dollars). These estimates are periodically reviewed by the electric utilities to accomodate changes in technology, regulations, etc.

TABLE I

NUCLEAR PLANTS IN COMMERCIAL OPERATION
APRIL 1984

	PLANT NAME	UTILITY	MWe*	Commercial Operation
1.	Arkansas Nuclear 1	Arkansas Power & Light Co.	850	12/74
2.	Arkansas Nuclear 2	Arkansas Power & Light Co.	912	3/80
3.	Beaver Valley 1	Duquesne Light Co.	835	4/77
4.	Big Rock Point	Consumers Power Co.	72	12/62
5.	Browns Ferry 1	Tennessee Valley Authority	1065	8/74
6.	Browns Ferry 2	Tennessee Valley Authority	1065	3/75
7.	Browns Ferry 3	Tennessee Valley Authority	1065	3/77
8.	Brunswick 1	Carolina Power & Light Co.	821	3/77
9.	Brunswick 2	Carolina Power & Light Co.	821	11/75
10.	Calvert Cliffs 1	Baltimore Gas & Electric Co.	845	5/75
11.	Calvert Cliffs 2	Baltimore Gas & Electric Co.	845	4/77
12.	Connecticut Yankee (Haddam)	Connecticut Yankee Atomic Power Co.	582	1/68
13.	Cooper	Nebraska Public Power Dist.	778	7/74
14.	Crystal River 3	Florida Power Corp.	825	3/77
15.	Davis Besse 1	Toledo Edison Co.	906	11/77
16.	DC Cook 1	Indiana & Michigan Elec. Co.	1030	8/75
17.	DC Cook 2	Indiana & Michigan Elec. Co.	1100	7/78
18.	Dresden 2	Commonwealth Edison Co.	794	8/70
19.	Dresden 3	Commonwealth Edison Co.	794	10/71
20.	Duane Arnold	Iowa Electric Light & Pwr Co.	538	5/74
21.	Fort Calhoun	Omaha Public Power District	478	9/73
22.	Fort St. Vrain	Public Svc.Co. of Colorado	330	1/79
23.	Hatch 1	Georgia Power Co.	777	12/75
24.	Hatch 2	Georgia Power Co.	784	8/79
25.	HB Robinson	Carolina Power & Light Co.	700	3/71
26.	Indian Point 2	Consolidated Edison Co. of NY	873	7/74
27.	Indian Point 3	Power Authority of the State of New York	965	8/76
28.	J A Fitzpatrick	Power Authority of State of NY	821	7/75
29.	J M Farley 1	Alabama Power Co.	829	12/77
30.	J M Farley 2	Alabama Power Co.	829	7/81
31.	Kewaunee	Wisconsin Public Service Co.	535	6/74
32.	LaCrosse	Dairyland Power Cooperative	50	11/69
33.	LaSalle 1	Commonwealth Edison Co.	1078	10/82
34.	Maine Yankee	Maine Yankee Atomic Power Co.	825	12/72
35.	McGuire 1	Duke Power Co.	1180	12/81
36.	McGuire 2	Duke Power Co.	1180	4/84
37.	Millstone 1	Northeast Nuclear Energy Co.	660	12/70
38.	Millstone 2	Northeast Nuclear Energy Co.	870	12/75
39.	Monticello	Northern States Power Co.	545	7/71
40.	Nine Mile Point 1	Niagara Mohawk Power Co.	620	12/69
41.	North Anna 1	Virginia Electric Power Co.	907	6/78
42.	North Anna 2	Virginia Electric Power Co.	907	12/80

Plants in Commercial Operation

	PLANT NAME	UTILITY	MWe	Commerical Operation
43.	Oconee 1	Duke Power Co.	887	7/73
44.	Oconee 2	Duke Power Co.	887	9/74
45.	Oconee 3	Duke Power Co.	887	12/74
46.	Oyster Creek	Jersey Central Pwr & Light Co.	650	12/69
47.	Palisades	Consumers Power Co.	805	12/71
48.	Peach Bottom 2	Philadelphia Electric Co.	1065	7/74
49.	Peach Bottom 3	Philadelphia Electric Co.	1065	12/74
50.	Pilgrim 1	Boston Edison Co.	655	12/72
51.	Point Beach 1	Wisconsin Electric Power Co.	497	12/70
52.	Point Beach 2	Wisconsin Electric Power Co.	497	10/72
53.	Prairie Island 1	Northern States Power Co.	530	12/73
54.	Prairie Island 2	Northern States Power Co.	530	12/74
55.	Quad Cities 1	Commonwealth Edison Co.	789	8/72
56.	Quad Cities 2	Commonwealth Edison Co.	789	10/72
57.	Rancho Seco 1	Sacramento Municipal Utility District	918	4/75
58.	R E Ginna	Rochester Gas & Electric Co.	470	3/70
59.	Salem 1	Public Service Elec & Gas Co.	1090	6/77
60.	Salem 2	Public Service Elec & Gas Co.	1115	10/81
61.	San Onofre 1	Southern California Edison Co.	436	1/68
62.	San Onofre 2	Southern California Edison Co.	1087	8/83
63.	San Onofre 3	Southern California Edison Co.	1100	4/84
64.	Sequoyah 1	Tennessee Valley Authority	1148	7/81
65.	Sequoyah 2	Tennessee Valley Authority	1148	6/82
66.	St. Lucie 1	Florida Power & Light Co.	830	12/76
67.	St. Lucie 2	Florida Power & Light Co.	804	7/83
68.	Summer 1	South Carolina Elec & Gas Co.	900	1/84
69.	Surry 1	Virginia Electric & Power Co.	788	12/72
70.	Surry 2	Virginia Electric & Power Co.	788	5/73
71.	Susquehanna 1	Pennsylvania Power & Light Co.	1065	6/83
72.	Trojan	Portland General Electric Co.	1130	5/76
73.	Turkey Point 3	Florida Power & Light Co.	693	12/72
74.	Turkey Point 4	Florida Power & Light Co.	693	9/73
75.	Vermont Yankee	Vermont Yankee Power Co.	514	11/72
76.	Yankee Rowe	Yankee Atomic Power Co.	175	6/61
77.	Zion 1	Commonwealth Edison Co.	1040	10/73
78.	Zion 2	Commonwealth Edison Co.	1040	9/74

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*Design Electric Rating (Net MWe), NUREG-0020, Licensed Operating Reactors, Vol.7, No.110, October 1983

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TABLE II

NUCLEAR PLANTS WITH FULL POWER OPERATING LICENSES AND NEAR COMMERCIAL OPERATION APRIL 1984

	PLANT NAME	UTILITY	MWe*
1.	LaSalle 2	Commonwealth Edison Co.	1078
2.	WPPSS 2	Washington Public Power Supply System	1100

NUCLEAR PLANTS WITH OPERATING LICENSES BUT CURRENTLY SHUTDOWN APRIL 1984

	PLANT NAME	UTILITY	MWe*
1.	Dresden 1	Commonwealth Edison Co.	275
2.	TMI 1	Metropolitan Edison Co.	819
3.	TMI 2	Metropolitan Edison Co.	906

NUCLEAR PLANTS WITH FUEL-LOAD OR LOW POWER OPERATING LICENSES APRIL 1984

	PLANT NAME	UTILITY	MWe*
1.	Diablo Canyon 1	Pacific Gas & Electric Co.	1084
2.	Grand Gulf 1	Mississippi Power & Light Co.	1250
3.	Susquehanna 2	Pennsylvania Power & Light Co.	1152

DOE OPERATED NUCLEAR PLANTS APRIL 1984

PLANT NAME	UTILITY	MWe*
Hanford-N	Department of Energy/ Washington Public Power Supply	860

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* Design Electric Rating (Net MWe), NUREG-0020, Licensed Operating Reactors, Vol.7, No. 110, October 1983.

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TABLE III

NUCLEAR PLANTS WITH CONSTRUCTION PERMITS AND A UTILITY SCHEDULED COMPLETION DATE

APRIL 1984

PLANT NAME	UTILITY	MWe	CLASS*	% COMPLETE	UNDER ACTIVE CONSTRUCTION
1. Bryon 1	Commonwealth Edison Co.	1175	1984	93	Yes
2. Callaway 1	Union Electric Co.	1120	1984	98	Yes
3. Catawba 1	Duke Power Co.	1145	1984	97.8	Yes
4. Comanche Peak 1	Texas Utilities	1150	1984	97	Yes
5. Enrico Fermi 2	Detroit Edison Co.	1154	1984	98	Yes
6. Limerick 1	Philadelphia Electric Co.	1065	1984	90	Yes
7. Midland 2	Consumers Power Co.	852	1984	85	Yes
8. Shoreham	Long Island Lighting Co.	849	1984	99	Yes
9. Waterford 3	Louisiana Power & Light Co.	1104	1984	99	Yes
10. Watts Bar 1	Tennessee Valley Authority	1170	1984	96	Yes
11. Wolf Creek 1	Kansas Gas & Electric Co.	1150	1984	90	Yes
12. Beaver Valley 2	Duquesne Light Co.	923	1985	78.1	Yes
13. Braidwood 1	Commonwealth Edison Co.	1175	1985	70	Yes
14. Byron 2	Commonwealth Edison Co.	1175	1985	67	Yes
15. Diablo Canyon 2	Pacific Gas & Electric Co.	1106	1985	95	Yes
16. Midland 1	Consumers Power Co.	504	1985	85	Temp. Halt 1983
17. Millstone 3	Northeast Nuclear Energy Co.	1150	1985	81	Yes
18. Palo Verde 1	Arizona Public Service Co.	1238	1985	99.5	Yes
19. Palo Verde 2	Arizona Public Service Co.	1238	1985	98.7	Yes
20. Perry 1	Cleveland Electric Illum. Co.	1205	1985	90	Yes
21. River Bend 1	Gulf States Utilities Co.	940	1985	82	Yes
22. Watts Bar 2	Tennessee Valley Authority	1170	1985	61	Yes
23. Braidwood 2	Commonwealth Edison Co.	1175	1986	54	Yes
24. Catawba 2	Duke Power Co.	1145	1986	61.9	Yes
25. Clinton 1	Illinois Power Co.	950	1986	82.4	Yes
26. Comanche Peak 2	Texas Utilities Co.	1150	1986	63	Yes
27. Hope Creek 1	Public Service Electric & Gas	1067	1986	81	Yes
28. Nine Mile Point 2	Niagara Mohawk Power Co.	1100	1986	78	Yes
29. Seabrook 1	Public Service Co. of New Hampshire	1200	1986	89	Temp. Halt 4/84
30. Shearon Harris 1	Carolina Power & Light Co.	900	1986	85	Yes
31. South Texas 1	Houston Lighting & Power Co.	1250	1986	50	Yes
32. Vogtle 1	Georgia Power Co.	1215	1986	61	Yes
33. Bellefonte 1	Tennessee Valley Authority	1262	1987	76	Yes
34. Grand Gulf 2	Mississippi Power & Light Co.	1250	1987	33.1	Minimum Effort
35. Palo Verde 3	Arizona Public Service Co.	1238	1987	83.2	Yes
36. Perry 2	Cleveland Electric Illum. Co.	1205	1988	42	Minimum Effort
37. South Texas 2	Houston Lighting & Power Co.	1250	1988	25	Yes
38. Vogtle 2	Georgia Power Co.	1215	1988	19.9	Yes
39. Bellefonte 2	Tennessee Valley Authority	1262	1989	57	Yes
40. Limerick 2	Philadelphia Electric Co.	1065	1990	30	Minimum Effort

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* Year of utility estimate of completed construction

4/4/84

TABLE IV

NUCLEAR PLANTS WITH CONSTRUCTION PERMITS BUT INDEFINITELY DELAYED APRIL 1984

	Plant Name	Utility	MWe*	Percent Complete
1.	Hartsville A1	Tennessee Valley Authority	1285	44
2.	Hartsville A2	Tennessee Valley Authority	1285	34
3.	Seabrook 2	Public Service Co. of New Hampshire	1200	29
4.	WPPSS 1	Washington Public Power Supply	1267	62.5
5.	WPPSS 3	Washington Public Power Supply	1260	75
6.	Yellow Creek 1	Tennessee Valley Authority	1375	35
7.	Yellow Creek 2	Tennessee Valley Authority	1375	3

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* Design Electric Rating (Net MWe), NUREG-0020, Licensed Operating Reactors, Vol. 7, No. 110, October 1983.

TABLE V

ANNOUNCED TERMINATIONS AND CANCELLATIONS OF NUCLEAR PLANTS 1982, 1983, 1984

Date of Cancellation	Plant Name	Utility	MWe	Type	CP/Issued	%Comp.
1) 8/26/82	Allens Creek	Houston Lighting & Power Co.	1200	BWR	N/I	0
2) 2/16/82	Black Fox 1	Public Service Co. of Oklahoma	1150	BWR	N/I	5%
3) 2/16/82	Black Fox 2	Public Service Co. of Oklahoma	1150	BWR	N/I	2%
4) 11/2/82	Cherokee 2	Duke Power Company	1280	PWR	12/30/77	N/A
5) 11/2/82	Cherokee 3	Duke Power Company	1280	PWR	12/30/77	N/A
6) 8/26/82	Hartsville B1	Tennessee Valley Authority	1233	BWR	6/9/77	17%
7) 8/26/82	Hartsville B2	Tennessee Valley Authority	1233	BWR	6/9/77	7%
8) 11/15/82	North Anna 3	Virginia Electric & Power Co.	907	PWR	7/26/74	8%
9) 10/82	Pebble Springs 1	Portland General	1280	PWR	N/I	0
10) 10/82	Pebble Springs 2	Portland General	1280	PWR	N/I	0
11) 2/23/82	Perkins 1	Duke Power Company	1280	PWR	N/I	0
12) 2/23/82	Perkins 2	Duke Power Company	1280	PWR	N/I	0
13) 2/23/82	Perkins 3	Duke Power Company	1280	PWR	N/I	0
14) 8/26/82	Phipps Bend 1	Tennessee Valley Authority	1233	BWR	1/16/78	27%
15) 8/26/82	Phipps Bend 2	Tennessee Valley Authority	1233	BWR	1/16/78	5%
16) 2/82	Vandalia	Iowa Power & Light Company	1270	PWR	N/I	0
17) 1/22/82	WPPSS 4	Washington Public Power Supply	1250	PWR	2/21/78	24.9%
18) 1/22/82	WPPSS 5	Washington Public Power Supply	1250	PWR	4/11/79	17%
19) 4/29/83	Cherokee 1	Duke Power Company	1280	PWR	12/30/77	18%
20) 10/14/83	Clinton 2	Illinois Power Company	933	BWR	2/24/76	1%
21) 12/21/83	Harris 2	Carolina Power & Light Company	900	PWR	1/27/78	4%
22) 8/30/83	Skagit 1	Puget Sound Power & Light Co.	1275	BWR	N/I	N/A
23) 8/30/83	Skagit 2	Puget Sound Power & Light Co.	1275	BWR	N/I	N/A
24) 10/26/83	Clinch River Breeder Reactor	DOE	375	LMFBR	N/I	N/A
25) 1984	Carroll County 1	Commonwealth Edison Company	1120	PWR	N/I	0
26) 1984	Carroll County 2	Commonwealth Edison Company	1120	PWR	N/I	0
27) 1/16/84	Marble Hill 1	Public Service Indiana	1130	PWR	4/4/78	59%
28) 1/16/84	Marble Hill 2	Public Service Indiana	1130	PWR	4/4/78	37%
29) 1/5/84	River Bend 2	Gulf States Utilities	934	BWR	3/25/77	1%
30) 1/21/84	Zimmer	Cincinnati Gas & Electric Co.	810	BWR	10/27/72	97%

N/I - Not Issued
N/A - Not Available

4/18/84

Mr. **Berick**. No, I don't, in this sense, Senator; where I think the industry—or where I used to think the industry would want to be in 1998 was that the repository would be in operation or at least under construction.

And in order for the repository to get to that stage there are a lot of very high hurdles, including NRC licensing and State approval, and site characterization.

Where we would disagree with our counterparts on the industry side is in order to get that far down the road, you have to make the early hurdles. And our concern is that by focusing on that 1998 date, almost fanatically at this point in the process, we are skewing the planning process, we are skewing our approach to the institutional relations with the States, because the States don't believe the Department is really being responsive to the level of technical and political sophistication and credibility to get through those early stages of getting public acceptability, convincing somebody that it's all right to build one of these in their backyard.

And it's our concern that the 1998 skews that process. If we are really making progress in 1998, I don't believe that missing that date by 2 years or 3 years is going to make that much difference.

Right now the utilities know that even if that repository went into operation it would only be taking about 1,700 metric tons of spent fuel a year. That's well below what the utilities would be generating in that year, and I think that's an optimistic number.

Under the best of circumstances, utilities are going to have to continue, and I think recognize that they will have to continue to be responsible for spent fuel storage well beyond that startup date.

That's just when we start, even in the act, even if we would meet that date, that's when we start.

So utilities are going to have to commit to additional storage capacity. The question is, should that date drive the program in the wrong directions? And it's our view that it is doing that right now.

Senator **Evans**. If you were placed in charge of the program and said that 1998 was an important year, do you believe that you could adequately carry through the processes that you mentioned and meet that date?

Mr. **Berick**. I don't believe we could fulfill the responsibilities under the act by that date. And at this point in the process, I would want to have the program planned out. As I said earlier, I would want to have the details of the program laid out. If it came up at the final date of fulfilling all those objectives at 2000 or 2001, I would want to know that. I could come back at that juncture and try to get concensus from States, utilities, other parties, the Nuclear Regulatory Commission about what might be done to reduce those times at the individual stages.

But what I would want first, right now at the beginning is the whole program laid out, and that's not what's happening.

What we're getting is something else. What we're getting is time line that gets us to 1998 whether or not that's realistic.

Senator **Evans**. Do you believe that one, or a multiple number of sites ought to be set forth? Do you agree with the goal?

Mr. **Berick**. The goal set in the act of developing the second repository?

Senator **Evans**. Yes.

Mr. **Berick**. There's obviously an equity issue involved in that. We think that the Department ought to be looking at the development of a second repository even for the purpose of covering its bases if the first siting schedule falls short.

Senator **Evans**. How about a first repository? I'm just talking about the fundamental concept. Do you agree with that?

Mr. **Berick**. We have been supportive throughout this process of going ahead with the geologic repository as the primary waste disposal option.

We have been very leary of the monitored retrievable storage approach as the alternative.

Senator **Evans**. Have you generally felt that a single site is either safer, more economically the best way to go, or would you feel that multiple sites are a better way to go?

I'm concerned here about whether you have any real concerns over the transportation of waste to whatever repository you have. You know, if you have a repository, particularly if it's one on the east coast. or the west coast, and many of the sites being examined happen to be at the perimeters of our country and will almost maximize transportation distances and, presumably, the potential of dangers that go along with any kind of transportation.

Do you believe a single site is appropriate or adequate, or would we be better off looking initially at multiple sites?

Mr. **Berick**. Well, we believe at this juncture that the Department ought to be pursuing multiple sites.

From a siting standpoint, the act requires two repositories at the outset to be pursued. We believe that's an appropriate course.

As far as the transportation impacts from a repository. We believe that ought to be something taken into account in the first repository siting decision also.

The act is fairly clear in the guidelines through some help from the chairman while this act was being drafted to require that transportation considerations and distance from sites that generate the waste be considered. And we think that's an appropriate siting criteria. It would not necessarily be the definitive criteria, by any stretch of the imagination, but it should be a criteria in siting the very first repository. We shouldn't wait for the second repository to balance the equity issue because of transportation. It ought to be something factored into the very beginning of the program.

Senator **Evans**. One final thing. Would it be possible for you to put together—your testimony points out a lot of the dangers and the difficulties and the potential delays, and it's sort of on the negative side of reaching the timeframe, the goal that we're seeking. Could you in turn give us something that approaches it from the other end, saying here we are in 1984, what do you think are the steps that are required and, in your view, the time requirements for a prudent manager to get us from here to the ultimate goal and, I guess from that, what you think that goal would be in terms of time?

Mr. **Berick**. I will attempt to do that. And where I will start from and where I urged the Congress and the Department to start from probably 3 years ago when I testified on the original legislation, was to start with the material presented by the Department to the Nuclear Regulatory Commission in the waste confidence proceeding, where they did lay out a detailed program management plan, including amounts of time it would take to submit bids at different stages, to develop designs at different stages.

That came up with a requirement of getting a repository on line by 2006. Now, the Waste Policy Act has cut short some of those stages. There is no longer a requirement for full environmental review at the front end of the process.

So that would be the starting point, and we would work back from there.

Senator EVANS. Well, that would be useful if you could just go through that. And from that, and from the point that we are now at, give us your best estimate of what the appropriate processes would be and where it would take us in terms of a final time.

Mr. BERICK. Be glad to, Senator.

Senator EVANS. I might just say as a final comment, Mr. Chairman, it's an irony that we're already into this process some distance, we're looking ahead 15 years and somehow John Kennedy could make a speech and we got to the Moon within 10 years. And I sometimes think that we have lost a little of our initiative over time and that we ought to be able to do some things faster than we now apparently are able to do.

Senator DOMENICI. Well, Senator, you sure hit it on the head.

I would like to ask—I wasn't going to ask any questions here, I'm going to give you some written ones.

I tend to disagree with part of your testimony as to intent. But let me give you the question in writing and you answer it. I express what I thought the intent was, that aspect that you raised.

But let me ask you this. The Environmental Policy Institute nuclear waste project, could you tell us, what is your mission in life, what are you about?

Mr. BERICK. Senator, as you probably know, the Institute devoted—and I personally devoted about 5 years of our resources trying to develop a nuclear waste law that we thought would get the rules on the table so that all parties, DOE, the States, the industry would know how the program was going to be carried out.

It's our mission in life now to make sure that that act is implemented to the fullest extent and that the program intent laid out in that act is carried out. That's my goal right now.

Senator DOMENICI. So would it be fair to say that if that law is carried out to its fullest intent, your mission in life would be to see that a nuclear waste disposal site is constructed?

Mr. BERICK. Yes, sir.

Senator DOMENICI. Now, when you use the words, "things are skewed by the 1988 date," there's a couple of ways to take that.

I take it that you were saying, or you could be saying there is not real compliance with what the law intended. Is that correct?

Mr. BERICK. No. I'm saying that the Department at this stage is letting that goal drive other kinds of decisions in the program that it shouldn't be driving right now, like the planning process.

We should know up front, especially in light of the fact that there is a monitored retrievable storage proposal coming up here in another year, how long it will really take to get the repository constructed, not simply what the target date was in the act, but how long the Department now believes, given its understanding of what the legal requirements in the act are, given its understanding of where it is in the program that it inherited, that existed prior to the act, how long it's really going to take, and then to tailor that program in an attempt to meet the directives of the act.

And what we're saying is that we're sort of putting the cart before the horse. We're putting the end point in the very first paragraph of our planning process. We're not concluding that.

Senator DOMENICI. Well, let me ask it this way, then I'll quit.

Are you saying that when we devised the law and plugged in 1998, that it's your opinion, given the mission that you have just described, as an expert and an involved person, it's your opinion that the Department cannot reach the goal and do what was prescribed by law adequately?

Mr. BERICK. Within that timeframe.

Senator DOMENICI. Well, that's what I said, by 1998.

Mr. BERICK. Yes.

Senator DOMENICI. So shouldn't that be a rather simple thing for us to—for the Congress of the United States to determine?

You're suggesting that since you're going to be involved you're not adversed to filing lawsuits, obviously not to deny the mission, but to accomplish the goal as you see it—if I read you right, you're not going to try to not let America get a repository, you're going to insist if you go to court that we do it according to law. Is that correct?

Mr. BERICK. Yes, sir.

Senator DOMENICI. All right. So if we were to ask the Department within the next 3 months to deliver to this committee an indepth prescription, detail by detail, time by time, how they're going to get to 1998, would you, in behalf of your organization, critique that and tell us in advance, since you really want us to do advance 15-year stuff, tell us what you think about it in detail?

Mr. BERICK. We would, and we have already begun that process in the sense that we have commented extensively on the Department's draft mission plan, which is exactly the kind of document that you're suggesting the Department should be preparing.

We have met with Department officials in the last couple of months. We are going to comment on the next version when it comes out later this month—I think April 23 is the current target date. We have been involved in that process and we will continue to be involved.

We will certainly provide our comments to this committee. I think we have already submitted for the record our comments on the earlier draft.

Senator DOMENICI. I think then we'll talk to the Senators on the minority side, but I think we ought to get the Department to follow up on this. I think we ought to know if you are right or not.

It's conceivable that we ought to be able to have this done by 1998. I tend to agree with my friend from Washington. On the other hand, maybe we made it such that it can't really get there and do what is required. In which event, we ought to know that. I don't think we ought to be putting them in a position where an organization as well equipped as yours to cause delay based upon appropriate interpretations, where right up front you're just damn near predicting that we're not going to get there because you're not going to let us get there. That's how I read it. And I think they ought to fix that quickly.

Mr. **Berick**. Well, Senator, I guess I would have to take some exception to the idea that my organization would make significant efforts to prevent the Department from getting there. And I would——

Senator **Domenici**. You mean if you found to your understanding of how they ought to be following the law is not being carried out, that you would not seek to force them to do it?

I'm not being——

Mr. **Berick**. Our interest is making sure that the repository is built safely and in an environmentally sound manner. And to the extent that we would perceive the Department not doing so, we would attempt to intervene.

But let me just say——

Senator **Domenici**. But wouldn't that be prima facie if they weren't complying? Wouldn't that almost——

Mr. **Berick**. No. Because it's our view, at least on the date, that that is a target, that that's not a fixed date; that we would not be in court tomorrow suing them of——

Senator **Domenici**. I'm sorry, I didn't mean that. What I'm saying is, if 2 years from now you find that something required in this law is not being complied with, it is the purpose of your organization to see to it that they comply.

Mr. **Berick**. Yes, sir.

Senator **Domenici**. If that moves the date out beyond 1998, that is not your concern. Your concern, as I read it, is to see that it's safely built in accordance with this law.

And I know you, and you're very good at your work, and if you're telling this committee up front that you do not think—you use the word "skewing" or whatever it is, that they're not going to get there the way they're presently set out and the path they're following, I think we ought to find out what we can right up front, because I think you will have a very serious impact on being a self-fulfilling prophet.

Mr. **Berick**. Well, there are five or six States that will probably beat me to it.

Senator **Domenici**. Well, you'll joint them, and you'll be as good as they or better, I'm convinced, from what I know.

I regret to have this exchange, but it's based on my professional evaluation of your professionalism. And I note that we're pretty close in this law to where your organization thought we ought to be in 1978. You were kind of advocating a law much like this.

Now, I don't know where you were when we actually passed it whether you thought it should be different. But, clearly, you had a very big impact on what we ended up writing.

Mr. **Berick**. We did not support it. And one of the reasons we did not support it was the schedule in the act we felt was pushing the train too fast down the track.

Senator **Domenici**. Well, having had this dialog, at least since I have a little bit to say here in this subcommittee, I'm going to see if I can make sure that we get you on record correcting some of the up-front errors, and I'm going to do that if I have to get you all together even up here at a table, because I think that would be very helpful to the program.

Did you have anything further, Senator?

Senator EVANS. Well, no, except to reiterate what I had asked for. I think that the two are important, your getting the material from the department for Mr. Berick to critique. But also I would like the independent, you know, step-by-step procedure that you think is—not only is rational to follow, but if you think there is a way to met the requirements of the act and to build a safe nuclear waste storage facility within the timeframe between now and 1998, or, if not, what year it is rational to expect.

Because, you know, you may be right, that the world isn't going to fall apart if a target date isn't precisely hit, but it sure is worthwhile to plan for and to try to reach some targets.

I must get back to the Moon shot. I hardly think that a nuclear storage facility is any more complex or difficult than standing up and saying, I think we ought to put a man on the Moon in 10 years, and then set about doing it and doing it successfully, and doing it without accident and without deaths—except for the one on the ground; a spectacularly successful program, probably a lot more complex than anything we're talking about here.

Senator DOMENICI. There is one difference that does come to mind, Senator. Regretably, Congress did not draw the prescription to get to the Moon, and that's very different from this. [Laughter.]

Is that correct, we drew the prescription and that's what you're talking about?

Mr. BERICK. But various Senators didn't have constitutents, at least none that we know of on the Moon who might be concerned about the impact of lunar modules crashing into it.

Senator DOMENICI. You mean with reference to the objections that will come as to any side including those that are in it, including——

Mr. BERICK. Yes, sir.

Senator DOMENICI. Well, we know that.

Senator EVANS. That just leads to one more question then.

Do you truly believe that under any set of circumstances we're likely to come through with that you any State with any site will welcome this with open arms?

Mr. BERICK. I don't believe that a State will welcome it with open arms, but that doesn't mean that it cannot be sited in a State.

I think the Waste Policy Act creates a situation where the State concerns and the national concerns in terms of siting that facility are balanced.

There was quite a controversy over where it would be two-house override or one-house override, but I think that the act does create the proper balance between the national interests and the interests that the State will have in making sure that if it is built, it's built safely and that it is represented in the decisions as to whether or not that facility will be built within its borders.

Senator EVANS. Mr. Chairman, I have got just one question.

Senator DOMENICI. Sure.

Senator EVANS. We have let Mr. Walker go without answering——

Mr. WALKER. I'm due at the corporation, so I have to go.

Senator Evans. We'd better hurry then. It's a question I won't ask you to answer right now, but I have got a fundamental question in this whole arena of the high-temperature gas reactors.

In your testimony you said,

> Confidence in the industry's ability to construct and operate plants of this size comes from recognition of the successes experienced by the nuclear-qualified utilities with large nuclear power facilities in the United States and abroad.

I guess I would have difficulty accepting that. It seems to me we have had over the years exceptional difficulty in this country, primarily because we wanted to be the biggest and the best and the most complex, and thought we would be the most efficient, and turned out to blow ourselves out of the water comparatively with countries which chose simpler, smaller, maybe Model T reactors, light-water reactors, but they've got a bunch of them operating, where we have a bunch of them sitting half-completed.

You are suggesting in your testimony the need to move toward some of the modular or smaller plants. And not now, now, but for our information it would be helpful to get your candid view as to which direction offers the most hope and the most potential and the most opportunity for us to handle something that's smaller, simpler, more straightforward, can be repliciated many times, or really, to spend the effort on bigger, more complex units which, in my view, in the light-water reactor have not proven to produce electricity a whole lot more economically than the smaller and simpler plants.

Mr. Walker. If I might, I could make a few comments now.

Unfortunately in our industry, you tend to hear about the bad examples. And I think the facts do show that there are a number of our utilities that have an outstanding record in the operation of their nuclear plants.

Senator Evans. I understand that.

Mr. Walker. You tend in anything to look at the bad ones.

Of course, the thrust of my testimony is we do have a window. We need to relook where we're going. And maybe we need to go back to simpler plants, smaller plants. That's what we're all about, to try to decide in this next year whether that's really where we ought to go.

And, of course, I'm a proponent of the high-temperature gas-cooled reactor, but I think that applies to some of the other concepts, too. And we're certainly going to endeavor to make a good decision on this before we go ahead, because we feel nuclear energy is vitally important to this Nation and we want to do it right.

That's a very brief answer, but I do need to get to another committee.

Senator Domenici. All right. We have some written questions we're going to submit to each of you, and you can answer them in the next 10 or 12 days. And we're going to see if we can arrange this other, the detailed layout, and see if we can get it to you. And if we're going to have a formal exchange or an informal one, we would like to have your evaluation.

Mr. Berick. We'd be most happy to.

Senator Domenici. Thank you very much.

[Whereupon, at 10:10 a.m., the committee recessed.]

Senator **Domenici**. Good morning.

We have Dr. Richard Schriever, Director of the Department of Energy, Inertial Fusion.

There are two public witnesses. We will get to them in short order. Let's take the Department of Energy witness first.

Your statement will be made a part of the record. We would appreciate your being as brief in your opening remarks as possible so that we can have time for a few questions.

Dr. **Schriever**. I see that you're pushing your next schedule, and we will dispense with the visuals that we planned to have used. They're included in the package, I believe, that you have.

Senator **Domenici**. Fine.

STATEMENT OF DR. RICHARD L. SCHRIEVER, DIRECTOR, OFFICE OF INERTIAL FUSION, DEPARTMENT OF ENERGY

Dr. **Schriever**. It's a pleasure for us to be here to discuss the Inertial Fusion Program with you again this year. And with the traffic this morning, it's a pleasure to be here at all. It was a really difficult time getting here.

The Inertial Fusion Program has as its major goal to learn how to burn a very small amount of thermonuclear fuel in a laboratory environment using beams either of particles or lasers to compress and heat the fuel.

This is an inertial fusion goal that is basically one of physics, and one of research, but it leads to two important applications.

Because we're involved in the study of high-temperature/high-density physics in a unique way, there is a great immediate payoff to the Nuclear Weapons Program.

We're involved in a number of things that provide us the ability to measure parameters and study materials in the laboratory that could otherwise only be done, perhaps, underground in Nevada.

As a long-term objective, if we are successful in the program that we're involved in—igniting thermonuclear fuel—we will have a great potential application for long-term development of fusion energy production.

In the recent past there's been a growing development and interest in our program because we have a unique capability to study things which are also of interest to the Directed Energy Program, the President's new Strategic Defense Initiative.

And so the capabilities that we have developed and put into the laboratories and now have in place have short-term applications to the Weapons Program for national defense, and the long-term secondary objective related to energy.

There are six major participants in this program, the three national weapons laboratories: Livermore National Laboratory, Los Alamos National Laboratory, and Sandia, Albuquerque Laboratory; and three major support contractors: KMS Fusion, the University of Rochester—and I know you will hear from both of those organizations this morning—and the Naval Research Laboratory.

In addition, we support on the order of 20 to 25 smaller activities in universities and industrial groups.

The recent past has been a time of great accomplishment and rapid scientific progress—in our program—not all of which we're free to discuss here today—and we would be glad to bring you up on that in a different situation if you would like it at some time. But that has been remarkable, and we feel we're gaining a very clear understanding of where we're going and what can come out of this program.

Now, I'd like to mention the budget request. The Department has requested a total of $138 million for this program in fiscal year 1985; $125 million of that is operating; I believe $9.5 million is for equipment—diagnostic and scientific instruments to support our program—and this year we're asking just $3.5 million for construction. This is what is required to complete the particle beam fusion accelerator at Sandia, and represents a significant decrease in our funding request for construction relative to the last several years. We have no construction anticipated beyond this at this time.

There are three major experimental areas, each headed up by a national laboratory. The first is the glass laser or short-wavelength laser experiments headed by Livermore. That includes our major short-wavelength experiments on the NOVA laser, which will be completed in 1985, and will be by far the largest laser ever put into this kind of an experimental program.

A number of major accomplishments this year in that program, particularly the completion of a laser called NOVETTE, which contains the first 2 of the 10 NOVA laser beams, and has been very successful in demonstrating the engineering performance and details of that hardware.

We feel that it has been very effective. We have learned things and improved and fixed things there that would have been very expensive had they had to be done in the full laser afterwards.

We have also been able to do a significant number of experiments with NOVETTE, because it is the largest short-wavelength laser in operation at this time.

In addition, in the area of glass laser experiments, we have a major participation by KMS Fusion of Ann Arbor, MI. They have been very active in doing smaller plasma physics experiments in support of upcoming NOVA experiments and in the development of techniques for fabricating the tiny complex targets that we use in these experiments.

In addition to these two participants, there are activities in a slightly different area, an unclassified area that we call direct drive, involving uniform illumination of pellets. The University of Rochester is the major area of activity there. They do direct drive experiments with their large 24-beam OMEGA laser.

This year they have converted six of those beams to operate at a much shorter wavelength, a blue color of light, and have achieved very significant results in working with the pellets with six beams in blue light. And so the Department of Energy has authorized Rochester to begin conversion of the full 24 beams to blue light so that they can continue those experiments. We find great promise in the work that's being done there.

The final participant in that area is the Naval Research Laboratory, involved in precision physics and measurements of the parameters of these interactions. They have recently developed a technique they call induced spatial incoherence, which is a fancy way to say they've learned to make the profile of the laser beam very smooth, much smoother than we're able to at other places. And we're going to continue that investigation this year.

The second major area of activity is the gas laser experiments, primarily the carbon dioxide laser ANTARES at Los Alamos and the experiments that we do there.

These experiments are different from the glass laser experiments because they work at a much different wavelength of light, and the interaction physics is different. The two are separate areas of activity, with a separate set of potentials and payoff.

ANTARES, the large laser, has been finished now and went into operation in January of this year, and has been already very effective in the experimental program that we have planned for its use.

In addition to the laser fusion work which is going on there, there's a great deal of interest within the traditional weapons program to use this laser for unique capabilities it has to study physics of interest. Physically behavior involving unstable hydrodynamics that we're looking at there is something that's of great interest to the weapons program, as well as inertial fusion.

The people involved in different concepts for the strategic defense initiative are also very excited and involved in the use of that system and will, I think, see great rewards there in the future.

In the Gas Laser Program at Los Alamos, they're also investigating an advanced laser technology called krypton fluoride, a laser that has potential as a more efficient short-wavelength laser that we might consider using in a higher-energy followon experiment to the work that we're doing at this time.

The final major area of the program we call pulse power, the generation of intense electron beams or ion beams, which is conducted primarily at Sandia Laboratory and with the support of NRL and Cornell University.

They are primarily concerned in this area with learning to generate, focus, and concentrate these ion beams to the very high densities and intensities that we need for inertial fusion experiments.

The principal experimental facility there, to be completed in January 1986, is the particle beam fusion accelerator, which we call PBFA II. It's on schedule and, as I mentioned, will be completed with that 1985 funding. We expect to see it operating in January 1986.

In the meantime, we have had a great deal of positive results and good performance out of the PBFA I machine, the one that I think you have seen and which is working there. It conducted 1,300 shots or experiments this year, which is extremely impressive for such a complicated high technology machine.

We also, as well as inertial fusion interest, find that there are a significant number of weapons and strategic-defense-initiative experiments and applications that we're able to address with that machine at Sandia.

And finally, as I mentioned, we have a small activity supporting a few tens of smaller contractors in universities where there exists a unique capability to contribute to our program that is not otherwise available to us, and we have asked less than $1 million to support that work.

We're using these facilities and will continue to use them on a program plan which I will outline for you.

We are devoting this work to the support of weapons physics experiments. We are supported, of course, by the weapons program. But the weapons program and the Department of Energy recognize as well that we have a real potential for a contribution to energy should we be successful in our goal to learn how to ignite small pellets. So energy remains as a long-term goal.

The plan involves finishing these three major facilities: ANTARES, which was completed and is now in operation; NOVA, the short-wavelength laser at Livermore, which will be operational at the end of this calendar year; and PBFA II, the particle beam fusion accelerator at Sandia, which will, we expect, be in operation very early in calendar year 1986.

We then intend to use the next few years to conduct as intense as possible a program, do the most effective experiments that we can devise to evaluate and build a data base which will give us a strong understanding of these fusion processes which we are beginning to get a good handle on.

Then in the latter part of this decade, specifically we plan right now for 1987, we want to turn to that data base and make an evaluation of inertial fusion, its potential both for weapons program applicability as well as for energy, and determine at that time the future directions and opportunities that exist in the program.

That's a brief outline. We have always been appreciative of this committee's support, and I think we would be prepared to answer any questions you have at this time, Senator.

[The prepared statement of Dr. Schriever follows:]

Senate Energy and Natural Resources Committee
Subcommittee on Energy Research and Development
April 5, 1984

Inertial Confinement Fusion

R. L. Schriever, Director
Office of Inertial Fusion
U.S. Department of Energy

Introduction

Inertial confinement fusion is a program to determine the feasibility of fusion using lasers and particle beams as the energy source. Small masses of fusion fuel -- deuterium and tritium -- contained in a pellet are irradiated by very short, high energy pulses of light or particles to bring about the conditions of high density and temperature required for fusion. In contrast to the low fuel density and long confinement times of magnetic fusion, inertial fusion would result in an instantaneous burst of energy from a compact mass of fuel reacting at high density. These conditions of high density and high temperature produce effects that are useful in nuclear weapons physics studies including the simulation of nuclear effects on a laboratory scale. Inertial fusion is one of the Department of Energy's defense programs and is carried out in the three nuclear weapons laboratories, at three additional laboratories outside the Department of Energy weapons complex, and by roughly twenty-five university and industrial contractors that are monitored through the Nevada Operations Office and the national laboratories.

Inertial fusion program capabilities -- pulsed high energy beam sources, codes for theoretical modeling, target materials and fabrication technology, and diagnostics -- are applicable to inertial fusion feasibility experiments, related nuclear weapon physics experiments, and to laboratory verification of some of the directed energy weapon concepts. Some physics issues, such as beam propagation and energy deposition in materials, are involved in all three of these areas. The inertial fusion program objective is to develop an understanding of these areas of high density, high temperature physics. In developing this understanding we will also determine the scientific feasibility of laser and particle beam driven fusion and the potential of inertial fusion as a future energy option.

The Department is requesting $138 million for inertial fusion research and development in fiscal year 1985. This total includes $125 million for operating expenses, $9.5 million for capital equipment, and $3.5 million for construction. The funds requested for operating expenses would support activities related to glass laser experiments at the Lawrence Livermore National Laboratory and KMS Fusion, Inc. in Ann Arbor, Michigan. The Laboratory for Laser Energetics at the University of Rochester, New York, and the Naval Research Laboratory at Washington, D. C. are investigating the feasibility of inertial fusion through direct illumination, sometimes called "direct drive," of the pellet by a laser beam. Gas laser experiments are conducted at the Los Alamos National Laboratory, and pulsed power development is conducted primarily at Sandia National Laboratories, Albuquerque. Capital equipment funding is requested to provide laboratory equipment for these experimental activities. The $3.5 million requested for construction would complete the funding of the Particle Beam Fusion Accelerator II at Sandia and keep this facility on schedule for completion early in fiscal year 1986.

Glass Laser Experiments

Inertial fusion activities involving glass laser experiments are conducted at the Lawrence Livermore National Laboratory and at KMS Fusion, Inc.

Recent accomplishments at Livermore include the use of the NOVETTE laser to demonstrate critical laser technology elements of the nearly completed NOVA laser. These key technologies include crystal array fabrication, techniques for finishing and coating large optics, and split-aperture, large-disk amplifier development. The NOVETTE laser facility is also being used to test design concepts for X-ray lasers, and to extend the inertial fusion data base to shorter laser wavelengths (quarter micrometer) at record-breaking energy levels (near one thousand joules). These achievements provide added confidence in projected experimental results for the NOVA laser.

Early in FY 1985, the NOVA frequency-converted glass laser at Livermore will begin operation. It is expected to attain new record energy levels of 50 to 100 kilojoules and operate at the 1.06 micron, 0.53 micron, and 0.35 micron wavelengths. The support laboratories will continue to address areas of physics central to the technology base necessary for inertial fusion.

Direct-Drive Experiments

Research on laser fusion was augmented by a number of key contributions at the University of Rochester.. In particular, the University of Rochester demonstrated the successful conversion of six beams of the OMEGA "direct drive" laser to frequency-tripled, or blue light, operation. Experiments at the University of

Rochester with blue light have demonstrated, as expected, more efficient energy absorption by the target. This in turn could lead to lower laser beam energies required for high thermonuclear yield.

In the past year, scientists at the Naval Research Laboratory have made contributions to the basic physics underlying inertial fusion. In particular, they recently conceived and demonstrated a technique, called induced spatial incoherence, to achieve uniform direct laser illumination of laser fusion targets. They also conducted a series of experiments to measure properties of hydrodynamic instabilities that influence the performance of both nuclear weapons and inertial fusion pellets.

Gas Laser Experiments

The Los Alamos National Laboratory has the responsibility for evaluating the feasibility of inertial fusion with long wavelength carbon dioxide laser drivers and related target concepts. Los Alamos also conducts research and development applicable to advanced gas lasers (e.g., carbon dioxide and krypton fluoride) and is responsible for target design and reactor studies in support of heavy ion fusion accelerator research under the Office of Energy Research. Contributions to the weapons program include the capabilities of the ANTARES facility, CENTURION experimental activities, and related target code development, target design, fabrication technology, and diagnostics development.

ANTARES, completed at the end of FY 1983, will provide an energy output five times greater than that previously available from the HELIOS CO_2 laser system retired in 1983. ANTARES will operate at a longer pulse duration and with flexibility for pulse shaping that was not available on the HELIOS laser. These operating features will greatly expand the parameter space accessible for exploring the viability of the long wavelength target concepts. The evaluation of carbon dioxide laser driven targets will be completed in FY 1985. ANTARES will continue to provide a useful research facility for study of generic issues, such as hydrodynamic stability and interfacial penetration, that are central to the scientific feasibility of inertial fusion as well as to weapons physics. Thus, in combination with weapons experiments, the ANTARES experimental activities will provide a basis for validating weapons design codes and for the conduct of experiments to evaluate directed energy weapons concepts. Specific concepts currently being considered relate to the physics of macroparticle acceleration by laser beams. These concepts will be explored with the ANTARES facility, taking advantage of the unique characteristics obtainable in the laboratory with such an intensely focused 10.6 micron laser beam.

Los Alamos is also pursuing, as a part of the program's low-cost driver technology evaluation, efforts to demonstrate large aperture amplifier operation and multiplexed pulse compression techniques for the krypton fluoride gas laser. This laser has the potential for scaling to energy levels necessary for high gain experiments, with design goals for cost that would be practical for such large facilities. Efforts are now under way to evaluate this technology by establishing the design characteristics of a 40 to 50 kilojoule short-wavelength KrF gas laser. Such a laser could be used to demonstrate the necessary component performance characteristics and the critical elements of the beam combining and pulse compression process for scaling to larger systems.

Pulsed Power Experiments

The particle beam program is centered at Sandia National Laboratories, Albuquerque. As in the case of the laser efforts at Livermore and Los Alamos, the program addresses two main development issues, the driver and the target. Target development is assisted by Los Alamos. Compared with laser drivers, the projected advantages of particle beams are significantly lower system cost per unit of driver energy, higher driver efficiency, and the ability to deliver large amounts of power to the target given adequate focusing. The key technical issues are the focusing, the energy concentration onto the target, and the development of a lithium ion source of great purity.

Earlier driver development experiments, which were carried out using protons as the accelerated particle, have established that heavier ions, such as lithium, are better suited for ignition. Following a successful campaign to screen various diode designs, the program has selected the Applied B-diode as the leading candidate design. An alternate design, the hybrid diode, is under continued investigation. The selection of the Applied B-diode was made several months ahead of schedule.

The main experimental facility at Sandia is the Particle Beam Fusion Accelerator I (PBFA I). Over 1300 separate shots have been completed on PBFA I. The facility now has an operational frequency of one shot per day. A large data base for both driver and beam physics has been accumulated. Major improvements have been made in beam focusing and the quality of power. In order to obtain as much data with lithium ions as possible, PBFA I activities will use a lithium source. PBFA I will operate until the end of FY 1985, when activities will shift to PBFA II. PBFA I will be modified thereafter as a weapon effects simulation facility.

PBFA II, which is scheduled for operation in January 1986, will have the capability of 30 megavolts and 3.5 megajoules, which makes it the only inertial fusion facility that has the potential of achieving ignition conditions. The construction of PBFA II is on schedule.

The pulsed power effort has a major relationship to weapons program activities. The implosion hydrodynamics studies are a significant source of nuclear weapon physics information. Both the pulsed power technology and data on the physics of particle beams are immediately applicable to directed-energy research and applications.

Supporting Research

Each year the Office of Inertial Fusion sets aside 1 to 2 percent of its total operating budget to fund supporting research efforts; that is, research activities undertaken by universities and industrial sources that support the goals of inertial fusion but are not necessarily or directly tied to efforts at the national laboratories. Typical current efforts include an investigation of multilayer optical coatings by Brigham Young University and an investigation into the growth of new laser crystal line host materials by two industrial sources. In conjunction with similar funding by the national laboratories, we have been able to support up to 20 such activities each year. Historically, these efforts not only provide a valuable resource but also ensure greater academic and industrial interest and participation in inertial fusion.

Program Plan

The Department's program plan for inertial fusion calls for a major decision on the future of the program in 1987. This decision was planned in 1983 in the expectation that all planned construction would have been completed and a data base established on experiments using the ANTARES, NOVA, PBFA II, OMEGA, and NRL facilities, as well as the classified HALITE/CENTURION activity. On the basis of these data we expect to be able to project with some confidence the requirements on driver energy and pellet design to achieve fusion. During this period the program is also supporting weapons activities by providing data and experimental capabilities for both present and possible future weapons research and development.

Recent accomplishments in experimental verification of key physics assumptions, advances in driver technology, and target fabrication and diagnostics development support continued efforts toward the program objectives. These capabilities are increasingly being used in direct support of weapons development goals. The major driver facilities are the largest experimental facilities developed within the weapons activities of the national laboratories. The inertial fusion program thus brings to this crucial national effort new capabilities and new scientific and technical talent that are an important part of its revitalization. The funding requested is the minimum required to continue progress toward the program goals and fulfill the objective of supporting weapons activities.

Senator **Domenici**. Thank you very much, Doctor.

I have three questions, so let me get right to the point.

If you will listen to this first one, it has a little bit of explanation on my part, and I may be wrong in my assessment.

For several years the requests for inertial confinement fusion have been below what any reasonable person would say were necessary to complete the machines that we're building and support the research on them.

Both the authorizing and appropriating committees here and the Congress have supported increases above the budget request each time.

Now we have one of the three facilities completed. That cost from what we can figure was about $62 million. Now, we will be shutting it down within 1 year of its initial operation it we fund the program at the requested level.

I might sound very parochial for criticising this request, because the facility that we're talking about is at Los Alamos. But as I understand it, the present thinking is that each of the other facilities under construction—which again our estimates are from your information will cost over $200 million in all—they're also planned to be shut down within about 1 year of their initial operation.

Now let me just ask a simple question. Is this what you, the scientific leader, what you had in mind when you originally requested these facilities?

Dr. **Schriever**. We certainly didn't have in mind to shut them down so quickly after their completion, because we felt that there were a great number of things that we could accomplish and, as suggested this morning, those things go well beyond inertial fusion experiments.

Senator **Domenici**. All right, I'm aware of that. So I would ask you this followup quickly here.

Will you provide us for the record a summary of the experimental programs that were originally proposed by DOE for each of these facilities at the time the estimate was given justifying their need, and also the time estimated for completion of each of them?

And as I understand it, Los Alamos has about 18 months of experiments already on the drawing board, and we want that for each of the facilities. How was that going to be planned?

Dr. **Schriever**. Yes, I certainly will do that.

[The information follows:]

The following projections of facility use appeared in data sheets submitted with the request for authorization of the three major facilities:

ANTARES(1976): "The program to be conducted in this facility will investigate the feasibility of using laser energy to initiate thermonuclear reactions by laser irradiation of suitable deuterium-tritium targets." In the FY 1981 request for final funding of the two-module facility, the project life of ANTARES was estimated to be three years before major upgrade.

NOVA(1977): "The purpose of this facility is to provide a high energy laser facility with characteristics adequate to provide full capability for carrying the laser fusion experimental program through a demonstration of scientific feasibility." The present NOVA project, a 10-beam, 50-100 kJ laser capable of operating at the second and third harmonics, was estimated at the time of rescoping of the project to have a life of three years.

PBFA II(1980): "The purpose of this project is to increase the power and energy of the Sandia Particle Beam Fusion Accelerator substantially and to provide a high average power technology laboratory. This Phase II of the Particle Beam Fusion Facility is directed at achieving net energy gain thermonuclear yields by heating and compressing deuterium-tritium (DT) fuel and demonstrating the repetitive pulse technology for fusion power reactor applications." In the FY 1985 budget request data sheets the PBFA II project life is estimated to be 10 years.

The present experimental plan for ANTARES as shown in the Project Transition Plan dated August 1983 is as follows:

FY 1984 Begin 40-kJ experiments with ANTARES
- o Instrument ANTARES target chamber
- o Calculate ANTARES target performance
- o Fabricate ANTARES targets

FY 1985 Perform scaling experiments on optimized ANTARES targets

FY 1986 Perform weapons physics experiments on ANTARES.

The experimental plans for NOVA set out in the Project Transition Plan dated December 1983 are:

FY 1985
- o Conduct weapons physics experimental campaign
- o Conduct fluid instability experiments applicable to ICF targets

FY 1986	o Verify the scaling of hohlraum conditions with infrared, green, and blue light with energy sufficient to test laser-plasma interaction lengths appropriate to high-gain targets o Achieve 500 times liquid density fuel compression
FY 1987	o Complete development of a thick shell cryogenic target o Complete development of high-speed NOVA diagnostics o Achieve 1000 times liquid density fuel compression
FY 1988	o Test symmetry and stability requirements for the hot-spot ignition concept o Demonstrate the hydrodynamic equivalence of NOVA targets to projected high-gain targets
FY 1989	o Continue weapons physics target experiments

The PBFA II Project Transition Plan has not yet been approved. Experimental plans will depend in part on the outcome of PBFA I experiments now under way, which will indicate the particle energy density that will be achievable on PBFA II with appropriate diode design. We expect that inertial fusion target experiments may well extend to 1990 and possibly beyond. As is the case with the other major facilities, it is difficult to anticipate the specific weapons program demands for the use of these facilities and the priorities that will be accorded these needs.

Senator Domenici. And I think you know that in a very real sense, I don't like to have to ask you this question, because I know the DOE requested about $19 million more for the program, but the OMB, in its review process, cut it back.

My guess is, and my position is that we're going to add the money again as we have done in the past.

We can't justify, in my opinion, if we want to continue with sophisticated equipment like this, we just can't build the most powerful laser just to flip a switch once or twice and then shut it down. I mean, I think we're going to lose support for spending money for projects like this. Sooner or later, somebody is going to say, well you just wait around until you know more about what you want, we're just not going to pay for these things.

I note you are smiling, and you don't have to comment, but I hope you would agree that it's going to be difficult to build machines like this for that short time of life.

Dr. Schriever. Yes. That's a grave concern to me and people in our program. We feel that the ultimate success of inertial fusion will require at least one additional facility, which will be much larger. And while we're working very hard on learning how we might build such a facility at a much lower cost, it will, nevertheless, be expensive.

It's always difficult to keep a program moving effectively because you like to start a new facility before the previous one is finished. And without demonstration of effective use, and the proper justification for these facilities, we would never be able to go ahead and succeed in that way. And what you have described certainly is an area that would raise the question, and we are concerned about this.

Senator Domenici. All right. I'm not going to take a lot more time, because we have two witnesses, and I'm sure Senator Evans has some questions.

But let me follow up with a second question, and I think it does flow rather logically from that first one that I talked with you about.

We're supposed to "evaluate"—and I use that word in quotes—this program in 1987 to see what we have accomplished and decide where we're supposed to be going or where we ought to go.

I don't understand how we're going to have a sufficient data base to do that if we're not going to fulfill our experimental goals and are required to shut down the facilities, as I just described.

So let me ask. Given that we don't seem to be able to get a realistic assessment out of OMB, would it be helpful if we were to set up a review of this program like we have for magnetic fusion? In that case my understanding is that researchers in the field make this review to arrive at this evaluation that we're now charged with doing, or you're charged with doing. Can something like that be set up to give you and those of us in Congress who are interested in seeing that this research is evaluated rather fairly some kind of significant guidance?

Dr. Schriever. Yes, sir. I think that's an excellent suggestion.

We have looked at this problem and this kind of a suggestion over the years. It's a very difficult thing to do properly. It's difficult to find knowledgeable people who are not also involved as participants. So at the present time we are working very hard, not because we have a conflict with the judgments of the Office of Management and Budget, but because on an absolute basis we see the need for this.

The feature of the magnetic fusion program is that it has a standing national advisory committee, and that's one way to do this kind of evaluation. There are shorter term evaluations, and we're working very hard at this time to put together something that would begin in the immediate future that would be helpful to us in explaining and justifying our program before we come back to talk to you again next year, and possibly could have some long-term extensions that would give a stability and recognition that would also be valuable to all of the people who have to make decisions and judgments about this program.

So we're working very hard on that and we would be glad to make an effort to keep you informed as we progress, and even have your suggestions and inputs into the way we're doing it.

Senator DOMENICI. I have another one, and I'm just going to give it to you in writing, and you can answer it.

We need you to describe the stumbling blocks that we didn't expect in the inertial fusion area and also the break-throughs that may have occurred.

We're not coming up with the predictions that even the Electric Power Research Institute was optimistic about.

In the late 1970's, we thought that the generation of machines that we were working on would break even, and I guess the only one that's done that, or has a chance would be the Particle Beam II at Sandia.

Dr. SCHRIEVER. That's correct, it has the potential.

Senator DOMENICI. But I think it would be good for us to get a little better understanding if you would describe the stumbling blocks we didn't expect and that the scientific community didn't expect and engineering community. And also, if there are some fringe things that were beneficial that might justify the fact that well, we're not there yet, but some good things have happened.

Dr. SCHRIEVER. Yes; we would be glad to do that. We're well prepared, I think.

[The information follows:]

The obstacles and breakthroughs experienced in inertial fusion R&D are difficult to describe adequately in an open hearing. In general, it can be said that in the early 1970's there were unknowns in the laser-target interaction that could be discovered only by building high energy, short pulse lasers By the mid-1970's initial experiments had revealed quite complex plasma phenomena, but it was necessary to scale up the laser energy significantly to begin learning which processes tended to dominate the interaction over the time history of the implosion as the pulse length, scale length, intensity, wavelength, etc. were varied. As you rightly infer, the decisions to build still larger facilities, which our codes predicted could drive targets to breakeven, were risky in the late 1970's because these scaling relations could not be predicted.

By the early 1980's sufficient understanding had been developed to make significant changes in the scope and direction of the three large projects. The risk was reduced with the CO_2 laser by downscoping ANTARES to two modules. After the University of Rochester developed and demonstrated efficient conversion of glass lasers to the second and third harmonics, a decision was made to trade off energy on NOVA with wave length conversion, resulting in the present 10-beam frequency-converted system. We expect that ANTARES and NOVA will in time establish a good understanding of the scaling with beam energy of important target interaction phenomena for long and short wavelengths respectively.

Recent experiments indicate that absorption of energy by the target is much more efficient at shorter wavelengths and that absorbed energy is coupled more efficiently to the fuel. At long wavelengths there are a number of target concepts to be tested on ANTARES before we can predict with confidence the utility of long wavelength light as a fusion driver.

In the pulse power area, the critical issue remains that of achieving sufficently high power density in the target region. The absorption of light ions is assumed to be "classical", that is, relatively free of the complex plasma effects that appeared in laser-target interactions in the mid-1970's.

In the laser fusion area, the most important breakthrough has been the development of efficient wavelength conversion, now being implemented on NOVA and OMEGA. In the particle beam area, many improvements in machine technology have made it practical to design PBFA II as a high voltage accelerator of light ions -- currently lithium is the ion of choice -- rather than electrons, as was planned in the early to mid-1970's. Distinct from these improvements in driver technology for fusion are a number of applications to weapons R&D that do not require fusion. These include applications to some of the new weapons concepts. The high energy pulsed beams developed for inertial fusion are proving to be effective tools for studying these concepts as well as areas of nuclear weapon physics.

Senator **Domenici**. Senator Evans.

Senator **Evans**. It's a little difficult for me to ask questions. My colleague has had a long history, and intimate history with this particular form of energy research, but it will be fascinating for me to catch up.

Do you have any feel as to the potential ahead as this is compared with magnetic fusion, which currently appears to have the most promise—or are the competitors still at work and you're representing one part of that and——

Dr. **Schriever**. I was going to say, there are many opinions on that, and I do have a strong one.

Senator **Evans**. You're not a neutral observer.

Dr. **Schriever**. I should say, and I think this is correct and fair, the Magnetic Fusion Program is much closer to working the problems that have to do with engineering development, to make one of their systems into a power reactor. Those are engineering tasks which go far beyond the research in either case.

Senator **Evans**. They're getting toward the prototype.

Dr. **Schriever**. They're beginning to do that.

Now, the nature of the programs is that they have to solve many of those engineering type problems to complete their experiments.

There's a little more independence between our experiments and the engineering.

Neither of us have demonstrated a net production of energy, and that remains ahead for both of us. I'm not sure, but perhaps we would expect them to do it a little sooner, but it's still an open question. Either or both could be successful in a short period of time.

Inertial fusion has potentially a much-easier-to-deal-with set of reactor concepts. That is, the engineering may be easier. We're able to separate the laser source of energy from the fusion pellet by some distance. We don't require magnets, and that's an engineering difficulty associated with magnetic fusion.

So I think the beauty of it is that the two approaches are rather independent, and not really competitive, but complementary. And some engineering difficulty, for example, which should occur in one of those fields and be very difficult to solve, may not even be there in the other.

Senator **Evans**. These fields, even though they both involve fusion, are so different that there's not likely to be much cross-connect in terms of both the problems and the resolution of those problems?

Dr. **Schriever**. That's basically true. Of course, there are common areas and problems.

Senator **Evans**. I'm sure there is.

Is containment in terms of energy production ultimately, is containment as much of a difficulty with inertial as with magnetic fusion?

Dr. **Schriever**. No. That's one of the areas where the two approaches are significantly different.

Let me just outline this briefly. The magnetic fusion techniques involve very tenuous plasmas of very large volumes which must be contained in place for seconds or minutes, depending, in order for the burn to occur. And the difficulty or challenge is to keep them held together and contained and away from the walls while that occurs.

In inertial fusion, we deal with a fuel mass which is very tiny, but at very, very high density, and so must be contained for a very short time. We allow the inertia of the pellet to hold it together while it burns. That's why we've come to the term of inertial fusion.

So containment presents very different issues. We have a difficulty in the tradeoff, though, because we have to get those materials to those very high densities. Once we get them together, containment is not an issue.

Senator **Evans**. Do you have any guess at this point, assuming adequate—and this is probably an unfair question, but assuming adequate resources and proceeding ahead, how long it might take before you could view something of this nature as possible commercial?

Dr. **Schriever**. Yes; that is a difficult question.

Senator **Evans**. I guess that has to assume that step by step, things prove out. Because if they don't prove out, obviously we may never get there.

Dr. **Schriever**. Let me identify a few milestones.

We feel that by 1986 or 1987, we will have built—certainly at least to our own satisfaction—a strong argument and verification of what would be required in terms of driver energy and pellet design to make a pellet burn.

Now, we have felt in the past that we were close to that, but we have a much stronger, more explicit, basis to say that now.

If that were done, and we were to go ahead, we might expect—and, of course, I'm guessing—another decade to build another very large machine which would demonstrate the actual production of energy from a given pellet.

So we're talking near the turn of the century. I think at that point we would be prepared in this country to begin to develop some kind of a reactor or electrical generating prototype. So I think we're talking sometime around 10 to 25 years after the turn of the century. That's speculation, of course.

Senator **Evans**. You mentioned 1987 as a decision time—well, before I ask that question; I'm unsure of the interconnect between the weapons and energy research. And, obviously you will tell me if some of the questions that I ask are ones that you can't answer in an open session.

But is this fundamentally research that gives you a better analysis of current nuclear weapons effects, or does it have a direct bearing on development of entirely new weapon systems?

Dr. **Schriever**. It does both of those things rather effectively.

Of course, we're not involved or interested in any weapons per se, construction of any weapons that involve lasers or the techniques that we have. But the very high temperatures of material, and the densities that we compress them to, and the very short time frames that we work in in the laboratory allow us to study processes that occur within weapons and within weapon explosions and allow us to then make contributions by measurement or verification of concepts or ideas, or determination of material parameters that have value to improvement of existing weapons, or the development of new ones, particularly the strategic defense directed energy weapons concepts.

Senator **Evans**. Well, when you say directed energy weapons, you're talking essentially the use of lasers for——

Dr. **Schriever**. Lasers, for example. Though our lasers are not pertinent to that sort of application.

Senator **Evans**. But the research which flows from them may well be?

Dr. **Schriever**. Yes; let me give you just one simple example. These lasers are able to deliver to a sample of material a very intense burst of energy, and that then becomes a mechanism to study the interaction of directed energy with a target.

Senator **Evans**. One final question on the interrelationship of energy research.

You manage one function, one area of research that we're engaged in in the energy field. How frequently, if ever, do you have an opportunity to sit in on sessions where there is a discussion and some attempt at decisions as to where we focus our overall energy research into various discrete areas and how much we should be putting into each one and how frequently do we review that on a comprehensive basis?

Dr. **Schriever**. I have opportunity, of course, to do that, but not great involvement in that process.

The Inertial Fusion Program is the responsibility of the Assistant Secretary for Defense Programs. The Magnetic Fusion Program, for example, is the responsibility of the Director of Energy Research.

There's a great deal of cooperation, interaction, and coupling in particular in the technical areas. But the Department of Energy treats inertial fusion essentially as a program in support of the Weapons Program and not as an Energy Program. And the Magnetic Fusion Program, of course, is primarily—or totally—seen as an Energy Program.

So I personally don't become involved in a great deal of that sort of thing.

Senator **Evans**. It's been a lonely quest. I have asked questions of almost everyone that's come in front of this committee engaged in one form or another of energy research and I haven't found one yet who says that there are any kind of sessions where the Department, much less the Federal Government—much less the country itself, tries to assess all of the ranges of energy research and try to make some discrete decisions as to where we ought to put our efforts—and more importantly, I guess, the relative importance of some, a review which seems to me is pretty fundamental to try to review regularly to see what kinds of progress we're making so we can intensify efforts one place or another.

You know, I voted in favor of continuation of the Clinch River breeder as an environmentalist. I caught a lot of hell by my environmentalist friends, but I pointed out to them that they wanted to dump all research in nuclear-associated areas, what did they think about the consequences of acid rain and greenhouse effects and other problems in the burning of fossil fuels.

It just seems to me that we've got a long way to go in finding our energy future. And I would like to think that we sometime would do it with, you know, an integrated and fairly obvious parallel basis, but with some idea from one of those parallels to the other as to what we're doing.

I know that's not your responsibility. That's my sermon for today, Mr. Chairman, and represents my continuing frustration.

Senator DOMENICI. I think it's a worthwhile frustration, and at some point in time we'll begin to get some of those kinds of answers.

Doctor, we're most appreciative. The questions I asked you to answer, we would appreciate them as soon as possible.

Dr. SCHRIEVER. We'll go right at them.

Senator DOMENICI. All right. Fine.

Let's take our two public witnesses. We have 15 minutes before this room must be available for the Secretary of the Interior.

Dr. Glass, president of KMS Fusion, Inc., and Dr. Robert McCrory, director of the Lab for Laser Energetics, University of Rochester, Rochester, NY.

Thank you, gentlemen. I'm sorry we don't have more time. I was hopeful we would have double the time, but you have been here and you know we did our best.

Dr. Glass.

STATEMENT OF DR. ALEXANDER J. GLASS, PRESIDENT, KMS FUSION, INC.

Dr. GLASS. Good morning, Mr. Chairman and Senator.

My name is Alexander Glass, president of KMS Fusion. I have submitted my written testimony for the record. I appreciate the very tight schedule we're on and I'll try to be brief.

I would like to recapitulate the main points of my testimony for the committee at this time.

KMS Fusion, as Dr. Schriever has indicated, is one of six laboratories currently involved in the Laser Fusion Program.

We are the only private participant, and I want to say just a few words about the unique role that a private company plays in a program like this.

Our company employs about 160 people, and we're located in Ann Arbor, MI.

KMS Fusion has been a pioneer in the Laser Fusion Program from the start. In fact, we're coming up on the 10th anniversary of one of the major events in this program; and that is, on May 1, 1974, the first successful laboratory demonstration of laser fusion took place at KMS Fusion in Ann Arbor.

Since then, the company has maintained a steady pace of innovation and has been a continuing source of new ideas within the program.

We have heard a lot about the relative advantages of short wavelength life versus longer wavelengths. KMS Fusion was the first laboratory to move to shorter wavelength by frequency conversion of the glass laser system. We were the first laboratory, and until this year the only laboratory in the world to successfully carry out experiments with cryogenic fuel; that is frozen fuel in the targets; a technique which we recently demonstrated has significant advantages over the gas-filled targets, and it's a technique which is now being adopted throughout the program.

As a support laboratory, as Dr. Schriever indicated, we are—our program is closely coordinated with the Lawrence Livermore Laboratory, the programs at the University of Rochester and the Naval Research Laboratory.

We operate a large glass laser system, and we also are a primary source of fuel containers, the tiny glass shells that are used to hold the hydrogen fuel for fusion research.

We're a primary source of those targets throughout the program, not only in regard to Livermore and the University of Rochester, but also to the Los Alamos National Laboratory. And on occasion we have supplied target components to Sandia.

We also have a commercial business; small, but nevertheless, it exists, of selling targets and target components overseas to European laboratories conducting laser fusion research.

Senator DOMENICI. Let me ask this question. In laser research, is your company merely a research company, or do you do other things, and this research is just part of a bigger business?

Dr. GLASS. At present, about 90 percent of our revenue is derived from the Laser Fusion Program. The remainder are in two areas; one is other Government-sponsored research, and the third area is commercial products.

In fact, one of the points I wanted to stress was that we are a—one of our primary objectives is to increase the share of our revenues which are derived from commercial products, and decrease our dependence on a single source of revenues and our dependence on sponsored research. And we have been the primary conduit for commercialization of technology developing in this program.

Senator DOMENICI. Please proceed.

Dr. GLASS. Thank you, sir.

In recent years in our experimental work we have concentrated on understanding the complicated processes which take place inside these microscopic laser fusion targets.

And in that regard, our work parallels closely that of my colleagues at the University of Rochester as well as in the national laboratories.

These experiments require extremely sophisticated instrumentation. We have to measure events which occur on a spacial scale of a hundredth of a milimeter or less, on a temperal scale of a fraction of a billionth of a second. And during those times and with that high degree of spacial resolution, we have to look at particle emissions, x rays and light

And this makes great demands on our ability to innovate experimental equipment. For example, we recently have developed a holographic camera, which enables us to capture the events which occur in an experiment; the experiment taking place in less than a billionth of a second. We can take four photographs of a target in that time; each exposure lasting less than 20 trillionths of a second. That is the world's fastest movie camera. I would also submit, it is the world's shortest movie.

As a private company, we're always on the lookout for opportunities for commercialization. And I think that is the unique world that a private company can play in this program.

As you have heard from previous witnesses, this is a long pull and we ought to be looking for the benefits that we can derive along the way.

This year we are marketing three products which come out of the ICF Program. One of them was developed jointly with the Los Alamos National Laboratory, and that's an optical shockwave detector. It's a minute glass shell, filled with argone gas on the end of an optical fiber. It was originally developed by Bob Benjamin, a scientist at Los Alamos, and we are now commercializing it.

We have also developed a video multiplexer, which is a device for hooking up several video terminals to a single hard-copy printer. And that's a product we introduced within the last 2 months. We're beginning to see sales in that area.

And one of the most exciting transfers of technology out of the Laser Fusion Program is in the area of biotechnology, where we have developed and are selling a microcarrier for the growth of living cells, genetically engineered cells. That microcarrier is a direct spinoff from our target fabrication work.

An additional benefit derives from the fact that the facilities that are developed in this program are useful for other Government programs.

We carried out during the past year several campaigns relating to the x ray laser project at Lawrence Livermore Lab. We had a team of researchers, involving workers from Livermore, from the Naval Research Laboratory, Imperial College in London, and our own staff. And these were critical experiments to define those systems which would be most likely to produce results in x ray laser experiments to be carried out on the larger lasers at Livermore this year and next year.

The Inertial Fusion Program has, as Dr. Schriever commented, invested in large facilities; NOVA, ANTARES, and PBFA II.

Our work is designed to provide a base of physics data, of target technology, of diagnostic instrumentation, and of experimental experience to maximize the cost effectiveness of these facilities.

The utility of the smaller facilities in this program—and they're only smaller by comparison, by the way, with the very large facilities at the national labs.

The utility of those facilities I think is clearly demonstrated by the x ray laser experiments. For example, had not a high turnaround facility been available, strongly supported in the areas of instrumentation and target fabrication, those experiments could not have taken place.

The availability of flexible, lower cost activity at the support laboratories is of great importance in deriving the maximum benefit from the very large investment the Government has made in the major facilities.

The ICF Program, as Dr. Schriever mentioned, has been making great progress. Unfortunately, classification restricts our ability to discuss that.

We have made great strides toward our goal of demonstrating ignition with a laser. We know that ICF works. It's only a question of, can we make it work on a reasonable scale?

Senator Domenici. Doctor, I'm going to have to ask you to quickly summarize. We have your statement. And I will submit to you a few questions that I have and you can answer them in writing, if you would.

Could you summarize, please?

Dr. GLASS. Yes, sir.

We feel this is not the time now to reduce budgets in the program. We feel there's a steady stream of new accomplishments, new facilities coming on line. A thorough scientific underpinning is being developed. Major advances in technology of targets and diagnostic equipment are being made. New commercial products are beginning to spin off from the program, and there are significant benefits to other Government programs.

I want to just close by acknowledging that we're grateful for the continuing support of this committee, and we ask your assistance in maintaining the health of this program at a critical juncture. Thank you.

[The prepared statement of Dr. Glass follows:]

STATEMENT ON INERTIAL FUSION RESEARCH

by

Alexander J. Glass
President, KMS Fusion, Inc.

Submitted to the Senate Energy and Natural Resources Subcommittee
on Energy Research and Development
April 5, 1984

SUMMARY

The 1985 Administration budget calls for a reduction in funding for all elements of the Inertial Confinement Fusion program. We feel that with major new facilities starting operation, and critical experiments scheduled in the next few years, these budget reductions are counter-productive, and will slow down the pace at which vital information will be obtained. We request an increase in funding for KMS Fusion, to the level of $14 million in FY 85 operating funds. This figure is less than the amount authorized for 1984. This modest increase will enable us to accelerate our efforts to acquire both the physics data base and the requisite target fabrication technology needed to make more cost effective use of the major facilities available to the ICF program.

The Inertial Fusion Program

Fusion is the process which generates the sun's radiant energy, and which gives the hydrogen bomb its awesome power. In fusion, the fuel, consisting of the heavy isotopes of hydrogen, called deuterium and tritium, is heated to a temperature of 100 million degrees, hotter than the sun's interior. At this temperature, the hydrogen nuclei fuse together to form helium, with an attendant release of energy. The fuel must be confined, i.e., held together long enough so that the energy released exceeds the energy invested to heat the fuel to the reaction temperature.

Inertial Confinement Fusion (ICF) is one approach to confining and heating fusion fuel. Energy from a powerful laser or particle beam is concentrated on a spherical shell containing the fuel. The fuel is heated and compressed in the process, until thermonuclear conditions are achieved at the center, igniting the fusion reaction. The surrounding compressed fuel is then ignited by a propagating thermonuclear burn wave, releasing energy from the fusion reaction.

Inertial Fusion research has been supported by the Congress for over a decade, with two objectives. In the near term, the ICF program provides information about thermonuclear physics which is of vital importance to the nuclear weapons program. In the long term, ICF is viewed as an alternative path to harnessing fusion as a source of energy. In the Department of Energy, the ICF program is administered by the Office of Inertial Fusion, under the overall direction of the Assistant Secretary for Defense Programs.

For the past five years, three major facilities have been under construction in the ICF program. Each represents a different technological approach to driving the inertial fusion process. The **Antares** laser, a 40 kilojoule, carbon dioxide laser at the Los Alamos National Laboratory, started operation in 1984. **Nova**, a 100 kilojoule glass laser, will commence operation at the Lawrence Livermore National Laboratory early in 1985. PBFA-II, a light-ion beam facility at the Sandia National Laboratory, is scheduled to start operation in 1986. These facilities, along with other activities in the ICF program, will provide the information needed to assess the scientific feasibility of inertial fusion late in this decade. The Department of Energy has scheduled a critical review of the ICF program in 1986-87.

The Nova Project

In 1979, the Department of Energy approved the construction of the Nova laser at LLNL. Nova was originally conceived as a 20-beam, neodymium-glass laser, capable of generating 200-300 kilojoules of infrared light in three-billionths of a second (3 nanoseconds). However, DOE only approved construction of a ten-beam system, designed to produce 100 kilojoules of infrared light, but with frequency conversion capability, to convert the output to visible light. The total project cost for Nova is approximately $176 Million.

There are two basic approaches to driving an inertial fusion target. The laser light can impinge directly on the target (direct drive), or can be converted to x-rays in an enclosure ("hohlraum") containing the fuel mass, and the x-rays used to drive the target (radiation drive). Radiation-driven targets offer better uniformity of illumination than direct-drive targets, but sacrifice efficiency at lower laser energies. Both approaches are currently under investigation in the ICF program. Nova experiments will emphasize the radiation-drive approach.

In order to ignite the fusion reaction, it is necessary to heat the fuel to 100 million degrees, and to compress it to 1000 times the density of liquid hydrogen (1000 x L.D.). Nova experiments are unlikely to achieve both conditions simultaneously. However, it is expected that targets will be compressed to 500 x L.D. in the first year of Nova's operation, at a temperature lower than that required for ignition. Subsequent Nova experiments are expected to achieve 1000 x L.D., at sub-ignition temperatures. Data from the Nova experiments, taken together with information obtained from other sources in the program, will define the driver and target requirements for both ignition and high-gain targets. These experiments will thus provide critical and valuable data for the ICF program, data which will provide the basis for evaluating the applicability of ICF to both its military and energy objectives.

The Role of KMS Fusion

KMS Fusion is a private company, located in Ann Arbor, Michigan, and is the only private participant in the ICF program. In 1979, KMS Fusion was designated as a support laboratory for glass laser experiments. Its efforts are closely coordinated with the program of the lead laboratory for glass laser experiments, LLNL. Cooperation among the laboratories in the program is fostered under this arrangement. Since 1980, in recognition of the high value of the Nova experiments, KMS Fusion has directed its efforts to support the Nova objectives.

KMS Fusion has played a major role in the development of inertial fusion. The company began fusion research in 1971. Ten years ago, the world's first successful demonstration of laser-produced thermonuclear reactions took place at KMS Fusion's laboratory, in Ann Arbor, Michigan. Since then, the company has contributed many other innovative "firsts" to the program. KMS Fusion was the first to carry out experiments with short wavelength light, a technique which has been subsequently adopted world-wide. The company pioneered the use of frozen (cryogenic) fuel in ICF targets, a complex technique generally acknowledged to lead to improved target performance. Until 1983, when LLNL conducted its first cryogenic target series, KMS Fusion was the only laboratory in the world to carry out cryogenic experiments. KMSF scientists had demonstrated, in 1981, that cryogenic targets perform better than gas-filled targets. Most recently, in 1983, the company developed a multi-frame holographic interferometer for visualizing the evolution of material above the surface of a target. This instrument is capable of providing stop-motion images in a fifty-billionth of a second. Up to four such images can be recorded during each experiment, which lasts less than a billionth of a second.

The company is a major supplier of targets and target components within the ICF program. The target fabrication effort comprises roughly half of the company's activities. This effort supports the internal research program at KMS Fusion, and also produces target materials and components for the other participants in the program. Several European laboratories also buy the sub-millimeter-sized glass Microshell® fuel containers that KMS Fusion has developed for fusion use. In addition to target fabrication, the company is pursuing long-term research to develop the large targets needed for the critical experiments to be performed on Nova. These targets involve several techniques and technologies developed at KMS Fusion, including cryogenic fuel, and various new target materials.

In addition to the company's efforts in materials science and target fabrication, KMS Fusion operates a highly productive experimental facility, the Chroma laser. Chroma is a two-beam laser, capable of producing up to 800 Joules of infrared light in a pulse of one billionth of a second duration. This energy can be efficiently converted to visible light, which couples more effectively to the fusion target. The laser is equipped with a pulse stacker, which allows us to synthesize pulses of arbitrary temporal shape, an important parameter for optimal target compression.

The Chroma laser is outfitted with two experimental areas. This allows us to carry out one set of experiments, while setting up another experimental configuration. At present, one experimental area is devoted to a unique optical system, devised and patented by KMS Fusion, which enables us to illuminate a target uniformly from all directions, with the light from the two beams of Chroma. Either gas-filled or cryogenic targets can be imploded in this target chamber, with either infrared or visible light. The second experimental area is used to explore the physics of radiation-driven targets. KMS Fusion is the only laboratory in the U.S. today actively exploring both directly driven and radiation-driven laser fusion targets.

Since 1980, the company has placed heavy emphasis on improving and developing its capability to detect and measure the complicated phenomena which occur within a fusion target. In any given experiment, it is necessary to measure effects on a spatial scale of hundredths of a millimeter, and a time scale of hundred-billionths of a second. The quantities measured include the density of the rapidly moving material vaporized by the incident laser energy, and the spectra of electrons, neutrons, ions, and x-rays over a wide range of energies. Today KMS Fusion has acquired the capability to measure all these quantities, simultaneously, with high accuracy. In developing our diagnostic capabilities, we have worked closely with the other laboratories in the program, especially LLNL, and gratefully acknowledge their cooperation and support.

By virtue of this increased diagnostic capability, and the flexibility and high data rate of the Chroma laser facility, KMS Fusion has become the principal source of information concerning the basic physics of radiation-driven targets in the ICF program. Over the past three years, we have conducted well over 1000 target shots on both radiation-driven and directly driven targets. These experiments have yielded basic and important information concerning the absorption of laser light by the target, the transport of energy within the target, and factors influencing the phenomenon of suprathermal electron generation, which limits target performance. These experiments have supplied data of vital importance to experiments performed on the Novette laser at LLNL, and scheduled to be conducted on Nova. A high degree of technical cooperation exists between the scientific staffs of the two laboratories, and the experimental results obtained at KMS Fusion are readily and quickly shared with the LLNL scientists as well as throughout the program. Both in target fabrication and in our experimental program, we are attempting to make the most cost-effective use of our facilities to support the near-term objective of the national program, the achievement of near-ignition conditions on Nova.

Technology Spin-Off

As the only private participant in the ICF program, KMS Fusion is the primary agent for the transfer of technology to commercial applications. Currently, KMS Fusion is marketing three commercial products which are based on technology developed within the ICF program. We have modified the tiny glass Microshell® containers, used to encapsulate fusion fuel, and have developed them for use as microcarriers for cell culture. Living cells, which produce biological materials such as vaccines, hormones, or interferon, can be grown *in vitro* on the surface of these microcarriers. Initial tests of our microcarriers have proven successful, and we are scaling up our production capability to commercial volumes.

In conjunction with scientists at LANL, we have also adapted our microshell® fuel containers for use as shockwave detectors. The tiny glass shells are filled with argon gas, and attached to the end of an optical fiber. An incident shock or pressure wave crushes the shell, causing the gas to emit a brief, intense pulse of light. This "optical pin" is currently in use in several laboratories studying shock and pressure phenomena, including LANL, KMS Fusion and other industrial laboratories.

Another product developed under the ICF program is the video multiplexer, a device which allows us to connect several video graphics terminals to a single hard-copy printer. Commercial sales of this product began early in 1984.

The availability of the facilities developed in the ICF program has provided a powerful stimulus for the investigation of x-ray lasers, both at LLNL and KMS Fusion. In 1983 and 1984, two experimental campaigns were conducted at the Chroma laser facility, involving KMS Fusion scientists working with researchers from LLNL, NRL, and Imperial College in London, England. These experiments were supported by a subcontract with LLNL, and have provided critically important spectroscopic data to guide the choice of experimental materials used in x-ray laser experiments conducted on Novette, and scheduled for the Nova facility. These investigations would not have been possible, were it not for the existing capabilities at KMS Fusion in target fabrication, diagnostic instrumentation, data analysis, and theory, as well as a high data-rate, reliable experimental facility, all of which were developed under the sponsorship of the ICF program, and company funding.

1985 Budget Request

In 1983, KMS Fusion received $10.5 Million in operating funds, approximately 7.5 percent of the program total. In 1984, operating funds for KMS Fusion were authorized at a level of $14.5 Million, but not fully appropriated. Our operating budget in 1984 is $10.8 Million, again approximately 7.5 percent of the program total. In 1985, we are requesting an increase in operating funds to the level of $14 Million, less than the amount authorized in 1984. As we stated last year before this committee, we feel that the moderate expansion of our program made possible by this budget increment will enable us to make far more effective use of our existing facilities and staff, in support of the objectives of the national ICF program, and in particular, will lead to more cost-effective use of the $176 Million Nova facility.

With added funding, we will increase our efforts in the development of critical target fabrication technologies. In the forthcoming Nova experiments, target performance will be limited by the ability to fabricate complex targets to the required specifications. We feel that this topic has not received adequate emphasis to date. Improving target performance through advances in target fabrication technology leads to more cost effective use of existing facilities. We will expand the development of polymeric materials for large fuel containers. These materials need to be strong, capable of holding fuel, and physically uniform. We need to accelerate the development of diagnostic gas fills for targets, a technique which provides characteristic signals from within the target to measure the temperature and pressure achieved in the implosion. Given our extensive experience in cryogenics, we feel it is urgent to accelerate the development of large cryogenic targets, along with techniques for characterizing the condition of the frozen fuel within the target. We have recently made the first demonstration of the formation of a homogeneous and uniform layer of liquid fuel in a large, cryogenic target. This technology is critical in the design of high-performance targets for Nova.

We cannot carry out the necessary expansion of these activities by reducing other efforts in target fabrication. We must continue to support the ongoing experimental programs in our own and other laboratories, because these are the source of the vital physics data needed to design high-performance targets. With added funding, we shall accelerate our own experimental program, with first priority given to maintaining a full schedule of experiments on radiation-driven targets. We need to expand our capability to analyze the experimental data we are generating. Both added staff and equipment are needed. Furthermore, we need to accelerate the investigation of directly-driven targets. KMS Fusion has a unique capability to carry out these experiments. Direct-drive targets may provide the best way to obtain data on ignition requirements and high density implosions, at limited laser energy. These experiments benefit from the ease of diagnostic access, and allow the early development and test of cryogenic targets, as our recent experiments have shown. Direct-drive experiments also provide an excellent test bed for physical measurements and comparison to theory, since the geometry of these experiments is essentially one-dimensional.

The University of Rochester operates the 24-beam Omega laser, which generates approximately 3 kilojoules of infrared light. To make the most cost-effective use of this facility, it should be converted to short wavelength operation, and equipped with cryogenic target capability. With added funding, KMS Fusion proposes to initiate the design and construction of a cryogenic target chamber for the Omega laser. With frequency conversion and cryogenic capabilities, it should be possible to carry out high-density target experiments, using Omega. These experiments would complement the direct-drive cryogenic experiments scheduled to be carried out at KMS Fusion late in 1984.

With added funding, we will also be able to accelerate the development of other required technologies. Diagnostic instrumentation remains an essential, and critical requirement, if we are to understand the complex phenomena which occur in a laser fusion experiment. We will develop diagnostic instrumentation on our facility, and transfer it to experiments at LLNL and elsewhere. We will also accelerate our investigations of new, cost-effective driver technology.

We are requesting a modest increase in funding for KMS Fusion in 1985, less than the amount authorized in 1984. This increment will enable us to accelerate our efforts in support of the major objectives of the national program, and will result in higher productivity in our own laboratory, and more cost-effective and timely use of the major facilities currently existing within the ICF program.

Senator DOMENICI. Thank you very much.

Let me just say that it's very tough for companies like yours to get in on the ground floor in this kind of endeavor. One of my questions was to tell this committee in writing how you were able to do that, and a couple of other things about it. We think that's something we should know a little more about.

Dr. GLASS. All right.

Senator DOMENICI. Dr. McCrory, would you proceed now. We have your detailed written remarks, and we have about 5 minutes.

STATEMENT OF DR. ROBERT L. McCRORY, DIRECTOR, LABORATORY FOR LASER ENERGETICS, UNIVERSITY OF ROCHESTER, NY

Dr. McCRORY. Thank you, Mr. Chairman.

Let me be mercifully brief, and go on record with my colleagues and say that I believe that the United States must support inertial fusion research vigorously over the period of the next 3 years in order for us to acquire the technical data that will lead to a rational basis for the technical decisions scheduled for 1987.

As you're aware, there are competing driver-target concepts, and at the present time, if we do not have the vigorous support of this committee and others, the country will not be able to achieve the scientific payoff that should come from the investment they've made in the facilities and in the scientists both at the support laboratories and at the very large-scale national facilities.

The inertial fusion research is vital, not only to the nuclear weapons development in this country, but I would say is indispensible in the energy mission facing this country.

Potentially there is a $10 to $100 trillion energy market in the 2lst century. If we are going to continue to have technological leadership that make us suppliers of that technology, these programs must go forward at the present time.

Our colleagues in Japan are pressing very, very hard to achieve a success in inertial fusion. And we must not cripple this program at the present time by reducing operations budgets below that required in order to get this data.

The University of Rochester has three distinct and complementary components. The first is the DOE-supported program where we do basic physics for the lead lab, and we're the major facility for direct-drive laser fusion.

We operate the national laser users facility and, as such, represent the only large-scale, unclassified facility open to qualified researchers in this country to conduct research on high-energy density matter energy and other things.

Our third component is a consortium of sponsors called the laser fusion feasibility project. Since 1971, we have been able to attract $108 million in total funding to the program. Of this, 48 percent is from non-Federal sources; that is, from our private sponsors, which include the university, the New York State ERDA, ESERCO, Northeast Utilities, Standard Oil, and most recently Southern California Edison.

We have a vital and unique mission in laser matter interaction data, capsule physics, diagnostics development, and laser optical engineering; all of which are the underpinning of DOE's defense programs in glass lasers.

We're particularly recognized for our 1980 invention and development of a highly efficient, tripling scheme where we convert existing glass lasers from the infrared to the ultraviolet.

Presently, scientific opinion is that the short-wavelength laser approach is most likely to succeed. Along those lines we are collaborating with Los Alamos on short-wavelength laser physics that are common to both the gas and glass laser programs. We collaborate with KMS on cryogenic experiments which should lead to high-density milestones by 1987. Also with Livermore on x-ray laser experiments. Wisconsin on preconceptual design of small fusion reactors.

Potentially, direct drive could lead to less than 500-megawatt plants, which is what our utility sponsors tell us would be highly desirable.

We did convert six beams this year, as Mr. Schriever testified. We need to convert all 24.

Let me close by noting that the proposed $6.2 million DOE budget for us in 1985 would not allow for the complete conversion of the system, although it's authorized, nor could we make effective use of the laser facility and acquire the data required for inertial fusion.

In 1982, we had to reduce staff approximately 25 percent in order to get on with the science. I cannot make further staff reductions without causing critical harm and needed program elements to fail.

I point out that the total request that we have is for $7.8 million, which is less than we actually received in fiscal year 1984. So we're certainly not expansionists. And I would urge this committee to give strong consideration to supporting inertial fusion research at the support laboratories and major facilities, and for the users—let me mention a few of them, the University of Florida, Connecticut, Pennsylvania, UCLA, Yale, Hawaii, Goddard, LANL, and it goes on.

So let me close by just adding to what my colleague, Dr. Glass has said to you, that we need the support if we're going to get the scientific payoff from this program.

Thank you.

[The prepared statement of Dr. McCrory follows:]

UNITED STATES SENATE

Ninety-Eighth Congress

COMMITTEE ON ENERGY and NATURAL RESOURCES

Testimony at a hearing before the

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

by

Robert L. McCrory

Director
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, New York 14623

April 5, 1984

Mr. Chairman and distinguished members of the Subcommittee, thank you for the invitation to appear before you today.

I shall briefly state my view of the objectives of the National Inertial Fusion Program and summarize the role of the University of Rochester's Laboratory for Laser Energetics in the glass laser program. My testimony will urge that the nation continue to support inertial fusion research, especially that conducted at the support laboratories, such as ours. All the inertial fusion research laboratories are productively acquiring the data required to make an intelligent program decision about inertial confinement fusion scheduled for 1987. It is critical to the inertial fusion program that the amount of time, staffing, and operations funding be adequate to acquire the technical data from competing driver-target approaches to ensure a rational scientific basis for the FY87 program evaluation. The nation's investment to date has been primarily in the development and construction of the facilities, at both the lead laboratories and the support laboratories, required to produce the data. From this point forward to 1987, the nation will reap the research results from it's investment. To reduce the program at this point would be ill-advised.

The National Inertial Fusion Program supports laboratory experiments which will determine the critical physics and engineering issues necessary to determine the scientific feasibility of igniting small fusion fuel masses. The present experimental strategy is to use laboratory drivers to acquire data which will help unambiguously determine the marginal ignition boundaries for small fuel mass systems. Although these data are vital to the nation's nuclear weapons physics research, they are indispensable in developing the prospects for inertial fusion as an energy source.

As a long-term strategy, the Inertial Fusion Program has the objective of demonstrating the feasibility of inertial fusion as a potent civilian energy resource. Achievement of the long-term objective requires the development of advanced driver technologies, as well as improvements in achievable target gain to produce an economically competitive and environmentally acceptable energy source. Any new energy source should be cost competitive with existing fossil or nuclear energy systems.

In order to address both the long- and short-term goals of the Inertial Fusion Program, as well as acquire the data base required for a predictive capability to determine the requirements for high-performance capsules, it is essential that continuing experiments should be conducted over the next three years. It would be a most unfortunate mistake for this nation, which has invested in these facilities over the past decade, to preclude the acquisition of the essential data necessary for a valid technical decision concerning inertial fusion by reducing the inertial fusion budget at this time.

The University of Rochester's assigned effort and role in inertial fusion is comprised of three distinct and complementary components: the DOE research program in direct-drive laser fusion, the operation of the facility for users (through the National Laser Users Facility (NLUF)), and the Laser Fusion Feasibility Project. The first two components are supported by the Department of Energy. The third, the Laser Fusion Feasibility Project, is supported by a consortium of sponsors, including the University of Rochester, New York State Energy Research and Development Authority, Empire State Electric Research Corporation, General Electric Company, Northeast Utilities Service Company, The Standard Oil Company, and Southern California Edison Company. To date, 48% of the $108 million funding for this program has come from non-federal sources. This represents the largest non-federal investment in inertial fusion research in this country. More than $37 million have been invested in building and laboratory equipment.

The Laboratory for Laser Energetics fulfills a vital and unique mission in this nation's Inertial Fusion Program by providing laser-matter interaction data, capsule physics, diagnostics development, and laser-optical engineering, the under pinning of DOE's defense programs in glass lasers. As an unclassified research facility, LLE plays a major role in the ultimate energy application of inertial fusion. Rochester has made numerous and critical contributions to high energy-density research, laser development, and optical engineering. Significant progress has been made at LLE towards demonstrating the feasibility of using ultraviolet wavelength lasers to directly illuminate fusion targets. In 1981, the OMEGA facility began its first series of twenty-four-beam, full-power, target shots which produced the highest thermonuclear yield efficiency obtained by any inertial fusion facility.

The Laboratory is particularly recognized for its 1980 invention and development breakthroughs in high-efficiency "conversion" techniques to produce ultraviolet laser light from existing high-power infrared lasers. These techniques greatly enhance the effectiveness of all glass lasers used in inertial fusion research, especially those at Livermore (LLNL). A productive collaboration between LLNL and LLE on laser development has existed for many years. As a result of the conversion work, glass lasers are now a potent research tool that will permit success in inertial fusion.

The Laboratory for Laser Energetics collaborates with institutions such as the University of Wisconsin, the Naval Research Laboratory, KMS Fusion Inc., the Los Alamos National Laboratory, and the Lawrence Livermore National Laboratory on various aspects of laser fusion. A collaboration with the University of Wisconsin, for example, has produced a conceptual direct-drive fusion reactor. The reactor named SIRIUS, after the brightest star in our sky, features a number of innovations including a dry wall made of silicon carbide which greatly reduces the neutron activation problem in fusion reactors. Collaborative experiments with Los Alamos have the objective of examining the scientific issues important to laser fusion and common to both glass- and gas-laser matter interactions. KMS Fusion Inc. provides many of the fusion targets used in Rochester's implosion experiments. Rochester and KMS are planning to use cryogenic targets in joint high-compression experiments. Rochester and NRL have closely interacted to address many of the issues related to the physics and basic scientific issues of reactor-sized targets.

In FY83, Rochester was authorized to convert six of the twenty-four OMEGA beams to the ultraviolet and thereby benefit from the 1980 breakthrough. The initial six-beam conversion and experiments were completed in the fall of 1983, on-time and on-budget, and exceeded the performance criteria established by DOE, according to the DOE report (Appendix A). An additional six beams are scheduled for conversion in 1984. Data, essential to meet the National Program plan for a 1987 assessment of inertial fusion, require the conversion of all (24) OMEGA beams, to the ultraviolet. Only with the complete conversion of the 24-beam system will it be possible to conduct the spherically symmetric, target implosion experiments which are necessary to meet the 1987 goals established by DOE. Rochester, and the other support laboratories in the glass laser program, provide data which strengthen the NOVA program at Livermore. In addition, the support laboratories help to develop a broad scientific constituency in inertial fusion by involving the industrial and university communities with the national laboratory efforts.

The Rochester laser facilities provided 2,806 shots for experiments during FY83. Our laser experiments have concentrated on the basic physics of coronal coupling, energy transport, and uniformity for short-wavelength, direct-drive laser fusion. These experiments have been especially beneficial for providing some of the critical data, needed but not otherwise available, to meet the milestones of the National

Inertial Fusion Program. The research activities of FY83 are summarized in Appendix B.

Scientific progress at Rochester undergoes annual review by an independent board of advisors — the Research Advisory Board (RAB) — appointed by the president of the University and made up of distinguished representatives from industry, universities, and national laboratories. A summary of the most recent RAB report is attached as Appendix C. The RAB reports have consistently acknowledged the high quality and success of the Rochester program in laser fusion and other areas.

In addition to its own important contributions to inertial fusion research, LLE operates the National Laser Users Facility, a major national resource, and the only open United States high-power laser laboratory available to qualified U.S. researchers from other institutions. Researchers from many laboratories and universities have participated in NLUF research. These institutions include the University of Florida, University of Connecticut, University of Pennsylvania, Yale University, UCLA, University of Maryland, University of Illinois, University of Hawaii, Polytechnic Institute of New York, the National Bureau of Standards, Naval Research Laboratory, Goddard Space Flight Center, Los Alamos National Laboratory, University of Texas at Dallas, Brigham Young University, and Physics International Company.

A major mission of LLE is educating students. Hundreds of students have been trained at LLE on state-of-the-art, high-power lasers, in the fields of plasma physics, optical engineering, materials science, and other disciplines needed to meet some of this nation's critical requirements. This training is indispensable to the future of U.S. technology, not only for inertial fusion but also for our national defense capabilities in general. Thirty-seven of these students have completed Ph.D research at LLE, and twenty-one are currently performing doctoral research. Graduates of the Rochester program are now making significant contributions at all major United States laser fusion laboratories as well as in U.S. industry and universities.

The proposed $6.2 million DOE budget in LLE in FY85 (see Appendix D) will not allow for complete conversion of the OMEGA system, the effective use of the laser facility, nor the acquisition of the data required for the 1987 DOE decision on inertial fusion. Rochester sacrificed staff (25% reduction-in-force) in FY82 in order to initiate the OMEGA conversion and maintain operations at the minimum level. If further staff reductions are effected, they cannot be made without causing other needed program elements to fail.

The complete conversion of the OMEGA system, the final 12 of the total 24 beams, requires an additional $1.4 million out of a required total appropriation of $7.76 million. The requested total appropriation, operations and equipment, is less than that for FY84. Had Rochester obtained the full funding originally agreed in the contract with DOE, it now would be conducting 24-beam ultraviolet experiments in addition to training significantly greater numbers of students and conducting more NLUF experiments.

In summary, the University of Rochester's Laboratory for Laser Energetics is on the threshold of attaining the capabilities required to carry out the experiments mandated by the 1987 National Program milestones. The Laboratory has an exceptional record of technical innovation and financial integrity. With stable funding from DOE, the demonstrated high-repetition rate and reliability of the OMEGA laser and the continued enthusiasm of an excellent research staff ensures that LLE will continue to be a vital and unique resource both for the National Inertial Fusion Program and for high-technology development in the United States.

Appendix A

Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, NV 89114-4100

RECEIVED
DEC 5 1983
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DIRECTOR'S OFFICE

NOV 2 9 1983

Dr. Robert McCrory, Director
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OMEGA CONVERSION

On November 2, 1984, the OMEGA Performance Review Group met to evaluate OMEGA 3ω performance of the first six beamlines and to determine if the performance criteria established on June 1, 1983, had been satisfied. The chairman of the Group subsequently reported the results of that review and the Group's recommendation to the Director, Office of Inertial Fusion (OIF).

Based on an assessment of the data presented, the Director, OIF, has concurred with the findings of the Review Group that all performance criteria had been met.

You are therefore authorized to proceed with the conversion to blue of an additional six beams during FY 1984.

Members of the Review Group and the Director commend you and your staff for the excellence of your presentation, and for your dedicated efforts during the preceeding months in completing the conversion and testing of the first six beams in such a timely manner.

Rex B Purcell
Rex B. Purcell
General Engineer
Resource Management & Budget Division

RMBD:RBP-865

Appendix B

Summary of Research Activities - 1983
Laboratory for Laser Energetics
University of Rochester

The fiscal year ending September 1983 (FY 83) was a productive one for the Laboratory for Laser Energetics (LLE). Progress in inertial confinement fusion was made by demonstrating the advantages of short-wavelength lasers for efficient coupling to fusion targets. Experiments at LLE with both the 24-beam, 1054-nm OMEGA facility and the single-beam, 351-nm, Glass Development Laser (GDL) system have concentrated on the physics of coronal coupling, energy transport and uniformity for short-wavelength, direct-drive laser fusion.

A major highlight was the completion, in the final quarter of the fiscal year, of the conversion of the first six 351-nm beams of the OMEGA system. An ultraviolet energy of over 300 J on target was achieved, and higher energies are expected as we gain confidence in the performance of the system. In support of this work, LLE developed a single monolithic frequency-conversion cell, similar to that developed at Livermore. The design takes advantage of the highly efficient frequency-tripling scheme originated at LLE, and uses a new index-matching liquid whose favorable damage-resistant properties were first established at LLE. The conversion cells installed on OMEGA have performed consistently for hundreds of shots, and have generated 351-nm energies in close agreement with theoretical predictions.

The laser facility operations continued at a high level. During FY83 the GDL and OMEGA facilities provided totals of 1724 and 1182 shots, respectively. GDL delivered 894 target shots in support of the various experimental programs, 422 shots for the damage-test facility and 408 miscellaneous system shots. OMEGA delivered 384 target shots in support of the drive uniformity, interaction physics, National Laser Users Facility (NLUF) and x-ray laser programs, and 798 shots for various system purposes including driver alignment, beamline calibration and UV conversion.

The Theoretical Division developed a new analysis of illumination uniformity on spherical targets using a spherical-harmonic decomposition of the energy deposition pattern of overlapping beams. Irradiation uniformity is estimated using this analysis from measured beam equivalent-target-plane profiles. The OMEGA system has been found to have no nonuniformities greater than approximately six percent in low-order spherical harmonic modes. Beam profile improvements demonstrated on GDL, together with a reduction of the OMEGA beam energy variance, are expected to yield irradiation nonuniformities a factor of three lower. The resulting irradiation symmetry will be close to that required for high-gain target implosions.

The Laboratory has now completed an extensive series of thermal transport experiments at 1054 nm on OMEGA. Thermal transport in spherical geometry has been found to differ markedly from transport in comparable single-beam target irradiation experiments, and cannot be described in terms of a simple transport model, whether flux-inhibited or uninhibited. Deep energy deposition in spherical irradiation (by electrons in the tail of the thermal velocity distribution) has been found to lead to a temperature profile which is not as steep as predicted by either transport model. Target implosion experiments have showed higher core temperatures than predicted by a flux-inhibited model, but lower densities than predicted by an unhibited-flux model. Further experiments are planned to substantiate some of the conclusions drawn on the basis of this campaign, and theoretical work on the development of improved transport models is currently in progress.

Harmonic and sub-harmonic emission measurements were made on spherical targets on OMEGA, providing important information about instability phenomena occurring in the underdense plasma corona. Emissions of $2\omega_0$ and $5\omega_0/2$ from the quarter-critical density region were observed for the first time. A systematic study of the spectral features of these emissions led to an improved understanding of their potential use as underdense plasma diagnostics. These emissions are also signatures of parametric processes which can lead to the generation of very energetic "superhot" electrons, and for this reason investigations of their dependence on wavelength, intensity and geometry were made on both GDL and OMEGA. Delineations between Stimulated Raman Scattering and the two-plasmon decay ($2\omega_p$) instability were made with 351-nm radiation in planar geometry, and, in spherical geometry, the $2\omega_p$ instability was identified as the principal generator of superhot electrons in 1054-nm experiments. Another important outcome of this work was the development of a new theory of the $2\omega_p$ instability; the plasma waves produced by this instability are also responsible for many of the harmonic emissions.

Detailed information on the production of energetic electrons were obtained from measurements on GDL of the continuum x-ray spectra produced by IR- and UV-generated laser plasmas. The spectra obtained from the 351-nm experiments lack a component ascribable to "hot" electrons produced by resonance absorption, in strong contrast to the spectra obtained using 1054-nm radiation. This result is important because it leads to the expectation that spherically irradiated targets at 351 nm will experience minimal electron preheat. Additionally, these spectra show a high-energy component at both wavelengths, due to a superhot electron distribution. On the basis of the correlation between intensity scaling of the superhot energy and the harmonic light emission from the target, the superhot distribution is attributable to the presence of the $2\omega_p$ instability, which appears to exceed threshold intensities at approximately 2×10^{14} W/cm^2 and saturate above 4×10^{14} W/cm^2. While the measured level of superhot electron production (less than 10^{-3} of the absorbed energy) does not present a serious preheat problem for laser-driven fusion targets, the targets and scale lengths used in these experiments are too small to allow the present results to be generalized to reactor-sized targets. It is important that future research should continue to monitor the superhot electron production in the underdense plasma when increased energies, and correspondingly greater intensity-length products, become available.

LLE significantly advanced the numbers and types of diagnostics available for measuring laser-fusion target interaction events. The diagnosis of laser-produced plasmas makes special and demanding requirements of x-ray spectroscopic techniques. During FY 1983 two x-ray instruments incorporating free-standing x-ray transmission gratings to provide broadband spectral resolution were developed. The first, a spectrally dispersive microscope, was used to obtain two-dimensional monochromatic spatial images of laser-fusion targets. This instrument has been used successfully to measure the spatial extent of the core of an imploded glass microballoon containing mixtures of deuterium and argon. The second instrument, a transmission-grating streak spectrograph, was developed and used to measure the target x-ray emission with simultaneous temporal and spectral resolution. Additionally, x-ray crystal devices were used in three new x-ray diagnostic developments: a Von Hamos x-ray spectrograph was developed and used to obtain measurements of ionic spectral lines in the 12-14-keV energy range; mosaic crystals were used in a geometry which yields both high sensitivity and resolution; and, finally, two-dimensional achromatic imaging demonstrated 10-μm resolution using Laue crystal diffraction.

Substantial progress was made in the theoretical understanding of the physics of high-energy-density plasmas. We investigated the effects of magnetic fields on electron heat transport in fusion targets, and elucidated the relationship between flux-limiting and magnetic-field-induced transport inhibition using a simple model which describes the transition between these two regimes in a physically reasonable way. For parameters corresponding to typical 1054-nm interaction experiments the theory shows that strong inhibition should occur for fields as small as 100 kilogauss, roughly an order of magnitude smaller than the megagauss fields which have been observed. At shorter laser wavelengths the plasmas are more collisional, and magnetic field effects are expected to be less important.

The LLE target fabrication group continued to enhance its ability to fabricate and characterize targets. One significant development is an improved interferometric technique, using a rotational-shearing interferometer, for the characterization of non-concentricity in transparent inertial-fusion targets. This technique offers distinct advantages for characterizing transparent targets; in particular, defects not easily visible using conventional target characterization techniques can be readily recognized, and the sensitivity of the instrument is not dependent on the target shell thickness. During the year the group has also investigated two polymeric materials for incorporating high-Z metallic elements into ablation layers. Sulfonated polystyrene neutralized with various alkali and alkaline-earth metals has been coated onto glass microballoons by solution dipping, producing an atomic-scale dispersion of the metal and the polymer with an extremely smooth surface. A metal-colloid-seeded polymer has also been coated by solution dipping. Although a homogeneous dispersion of metal is not achieved, metal colloids are dispersed as small particles of size of the order of 50 Å. This technique has the particular advantage that almost any metallic element can be used for the colloid. In another development, the drill-fill-and-plug target fabrication capability has been extended and improved, with the result that the mass perturbation caused by the plug has been reduced by at least two orders of magnitude. This increased target uniformity should contribute significantly to the success of high-compression implosion experiments planned for the future.

In our advanced technology areas, our technique for time-resolving electrical signals with sub-picosecond resolution, based on the Pockels effect induced in a traveling-wave electro-optic modulator, demonstrated an unprecedented bandwidth of 1 THz for electronic sampling. We expect this technique to be of importance in the study of laser-semiconductor interactions, in the propagation of electrical pulses, and in the characterization of ultra-fast electronic components. A second sampling technique has been developed which uses electron pulses rather than optical pulses to interrogate an unknown electrical signal. This new technique, "electron-optic sampling," samples electrical signals directly by probing their electric fields with electrons. The temporal resolution is currently around 35 ps, but a resolution of a few picoseconds appears possible in the near future.

Work continued on the LLE picosecond biophysics facility, in collaboration with outside users; here the energy transitions and deformations of photosensitive biomolecules are studied through observations of their fluorescent responses on very short timescales. Research this year included studies of the primary processes of photosynthesis using spinach chloroplasts, and investigations of large-scale structural changes occurring in the macromolecules DNA and HSA (human serum albumin).

LLE is developing laser-driven x-ray sources as a potent analytic tool to address a broad range of scientific and technological problems by extending our capabilities for time-resolved measurements on bulk structures. We used the GDL x-ray diffraction facility to obtain results on the time-resolved x-ray diffraction patterns from photostimulated biological systems such as sarcoplasmic reticulum, and dipalmitoyl lecithin.

The GDL facility was also used to obtain the first successful demonstration of a single-shot sub-micron-resolution x-ray lithograph using a laser-produced plasma as an x-ray source. The favorable exposure characteristics achieved make the laser-produced x-ray source promising for sub-micron lithography.

A collaborative experiment with Lawrence Livermore National Laboratory (LLNL) was conducted in order to investigate a laser-pumped photoabsorption x-ray laser. Eight beams of OMEGA, configured to produce a line focus, were used to irradiate an x-ray flashlamp target. The soft x rays produced in this interaction cause a rapid photoionization of Ne I to Ne II, creating a transient population inversion between the 2p and 2s states of Ne II. In this experiment a large number of new diagnostics were successfully activated and new methods were developed for target and beam alignment. We anticipate future experiments to investigate further the performance and potential of this approach towards the development of laboratory x-ray lasers.

In the LLE optical materials group, progress was made in several areas. In the key area of materials damage, it was demonstrated that sub-micron impurities in optical coatings can be detected using our photothermal-deflection microscopy system. In the future, research will be focused on identifying the exact nature of these damage-causing impurities; optical coatings of increased damage resistance will then be obtained by controlling impurities in the manufacturing processes. The group also developed and successfully tested liquid-crystal devices such as laser-blocking notch filters. Optical elements which exhibit low transmittance at a specific laser wavelength, and high transmittance at other wavelengths, are required to filter optical radiation incident on diagnostics or imaging systems; additionally, laser goggles for eye protection of personnel constitutes another area where these filters are useful. Research is continuing to determine the factors which limit the use of liquid crystals as notch filters over the entire optical spectrum.

The National Laser Users Facility, a unique national resource, enjoyed a successful year. User experiments conducted during this year (368 target shots) are summarized in the table below:

Table 1

NATIONAL LASER USERS FACILITY

FY 1983 SUMMARY

Principal Investigator	Affiliations	Experiment	Number of Shots
Prof. F. Chen	UCLA & Yale U.	Plasma Instabilities	105
Prof. J. K. Blasie Prof. L. Herbette	U. of Pennsylvania U. of Connecticut	Biophysics	77
Dr. R. Elton	Naval Research Laboratory	X-Ray Laser	25
Dr. J. Forsyth	U. of Rochester	Biophysics	107
Dr. U. Feldman	Naval Research Laboratory	EUV Spectroscopy	32
Prof. H. Griem	U. of Maryland	Line Shifts	15
Prof. G. Miley	U. of Illinois	Particle Energy Loss	5
Dr. B. Yaakobi	U. of Rochester	X-Ray Diagnostics	2

In addition to its research mission, the Laboratory continues to maintain an important role in student training. During FY83, twenty-one Ph.D. thesis projects were in progress. In the Department of Mechanical Engineering, several students are investigating basic phemonena in laser-produced plasmas. One theoretical project concerns the $2\omega_p$ and Raman instabilities at oblique angles of incidence; an understanding of the scaling of these parametric processes is required for success in direct-drive laser fusion. Other students are investigating thermal transport, hydrodynamic efficiency and time-dependent ionization phenomena. In the Department of Physics and Astronomy, a student is investigating hot-electron behavior - a regime currently of interest to the semiconductor industry. Students and faculty from the Institute of Optics are investigating picosecond electro-optical sampling techniques, synchronous amplification of subpicosecond pulses, level inversions in laser-produced plasmas, and a variety of other basic laser-matter research areas. In the Department of Electrical Engineering, one student is investigating the propagation of electromagnetic waves in strip lines. This thesis may result in the development of a successful pulse-shaping technique for high-power fusion lasers.

Looking to the future, additional OMEGA beamlines will be converted for 351-nm operation. Based on our experience with the first six frequency-converted beams, we project energies of around 2 kJ to be available for experiments when all twenty-four beams are operational in the UV. We then expect to perform significant spherically symmetric ablative target-implosion experiments, which will help to define the conditions necessary for establishing the scientific feasibility of inertial confinement fusion. The demonstrated high repetition rate and system reliability of OMEGA give us confidence that the LLE facility will continue to be a valuable resource both for the National inertial fusion program and for other users of the system.

Robert L. McCrory, Jr.
DIRECTOR
Laboratory for Laser Energetics
University of Rochester

Appendix C

RESEARCH ADVISORY BOARD

Dr. Harold K. Forsen, Chairman

1 June 1983

Mr. Robert L. Sproull
President
UNIVERSITY OF ROCHESTER
Rochester, NY 14627

Dear President Sproull:

The Research Advisory Board for the Laboratory for Laser Energetics met on June 1, 1983 to review progress in the program. A number of initial conclusions were formed which we would like to forward for your consideration and use.

The Board concurs with the Laboratory management's difficult decision to effect staff reductions in order to proceed with conversion of the OMEGA system to BLUE light operation. We strongly encourage efforts to secure sufficient funding to permit timely conversion of all twenty-four (24) beams to proceed.

Research activities leading to the understanding of irradiation and drive uniformity of symmetric targets continues to be of a very high caliber with the theory and experimental programs well integrated. Similar comments can be made about the work going on in hydrodynamic stability and target fabrication requirements for stable and symmetric implosions. It is particularly encouraging to see that the uniformity requirements for direct-drive laser fusion are being addressed in a very scientific manner, so that quantitative criteria for the laser and focussing are being established. The beam uniformity achieved is impressive. These result give increasing confidence that direct-drive will be successful. This work appears to be well on track and at the forefront of research in laser fusion.

We were also favorably impressed with the broader research program in x-ray lasers, microstructures analysis, picosecond research, materials, and the applications in which these technologies may be used. Expanded work in these and other appropriate areas are to be broadly encouraged.

The high caliber of the staff continues to be impressive. We are pleased that their spirit and dedication to the objective of the program remains high. Involvement of graduate students to further these goals and to provide researchers for further investigation into these important areas is also encouraging and should be expanded.

Finally, a successful and timely search for a new director has been concluded with the selection of Dr. Robert L. McCrory, who is a knowledgeable, dynamic scientist, and should be able to provide the cohesive and stimulating leadership that has characterized this program in the past.

You should feel very proud of this unique national program of university research. A response to specific questions posed to the Board will be forthcoming, but should a need arise for additional input, please free to call any of us.

Sincerely,

HKForsen

Harold K. Forsen
for the Committee

HKF/bla

Bechtel Group, Inc.

Fifty Beale Street
San Francisco, California
Mail Address: P.O. Box 3965, San Francisco, CA 9411

PRESIDENT'S OFFI
JUL 25 1983

July 19, 1983

Dr. Robert L. Sproull, President
University of Rochester
Rochester, NY 14627

Dear President Sproull,

Please excuse the delay in getting you a response from the Research Advisory Board for the Laboratory for Laser Energetics. We had an excellent review of the program on May 31 and June 1, 1983 and, as before, we were most impressed with what we saw and heard. Specific answers to posed questions are provided in the attachment, but there are several comments the Board encouraged me to pass back to you.

We continue to be impressed by the high calibre of the LLE's performance. For the size of the effort and the resources with which they work, LLE is making an outstanding contribution. It is also refreshing to view the energetic, competent beginnings by the new Director. Your success in choosing such individuals is to be commended.

The LLE is the only US laboratory with a credible direct drive program. While we are certain that you understand this, others may not, and therefore it may be important to state here.

Finally, the technical work performed during the past year certainly demonstrates that it may be possible to provide adequate uniformity over the target to directly drive imploding targets.

We enjoyed our visit, the hospitality shown us all, and we thank you for the opportunity to review an exciting program.

Very truly yours,

H K Forsen

Harold K. Forsen, Chairman
For the Research Advisory Board

HKF:pt
Attachment
cc: J.F.Barnes
G. Bekefi
J.M.Burger
R.W.Goodrich
H.Hurwitz,Jr.
M.N.Rosenbluth
I.L.White
J.Wilson

Bechtel Power Corporation
Bechtel Petroleum Inc
Bechtel Civil & Minerals Inc
Principal Operating Companies of Bechtel Group Inc

UNIVERSITY OF ROCHESTER
LABORATORY FOR LASER ENERGETICS
RESEARCH ADVISORY BOARD MEETING
May 31, 1983

QUESTIONS FOR CONSIDERATION AND RESPONSE

#1 Advanced Research

The portion of LLE efforts spent on non-fusion, high-technology research and development, such as micro-structure analysis, high-speed electronics, and various aspects of biotechnology, has been steadily growing in spite of declining LLE funding. Do you believe the balance between the Laboratory's inertial fusion program and these other programs is correct?

Presently several scientists at LLE are seeking additional funding for some of these non-fusion areas. Potentially, this activity could bring significant positive support to the laboratory. Can the committee provide suggestions for extra-program support possibilities?

Response: The Board was impressed with the research in non-fusion areas and feels that such work is essential, as it will provide a broad scientific base on which to build the fusion work and will therefore have a synergistic effect. In addition, this work is in general more appropriate for student research than is the fusion work, in that a student is more likely to find a project that can be pursued individually for a thesis in this area. We see a higher probability of finding financial support in the non-fusion areas, which is a further reason for continuing such work. We caution, however, that, although the Board would like to see more effort in the non-fusion areas, we do not want it to be at the expense of fusion research.

With regard to finding additional funds, the Board recommends that a search be made for likely customers of the new technologies. The microstructure analysis and x-ray work is of interest to the solid-state community, and sources of funding from this community should be sought. Since an x-ray light source is a competitor for synchrotron x-ray generation, the customers of synchrotrons should be contacted. Synchrotrons have plenty of users, and it should be possible to attract some if an appropriate user x-ray facility could be created. Strong interest is developing in the possibility of laser acceleration of particles. There are several possible applications, from research to industrial, to weapons (creating the possibility of DOD funds). This combination of high power lasers and plasma physics is very appropriate for LLE.

#2 Laser Fusion Program Objectives

In view of the general state of fusion research, do you believe that the objectives of the LLE laser fusion program are appropriate? In view of the current and probable future resources available to LLE, do you believe that the objectives of the LLE laser fusion program are realistic?

Response: The LLE program on the direct drive approach to fusion is appropriately and realistically structured towards establishing the basic physics needed to determine the feasibility of this concept. This broad based emphasis on carefully investigating the various parameters of this concept is preferable to a more narrowly structured effort aimed at demonstrating ignition at as early a date as possible. The conversion of the OMEGA laser to blue light is being aggressively pursued, and the Board continues to encourage this emphasis with the objective of implementation of the full 24-beam system as rapidly as funds can be secured. These funding objectives are within the reach of the program and should continue to be pursued vigorously.

#3 Direct-Drive Laser Fusion Demonstration

Is there a particular calculation or experiment that LLE can carry out that could convince the scientific community of the feasibility of the direct-drive approach to laser fusion? Is the Laboratory effective in presenting scientific results to the public and to the sponsors?

Response: The Research Advisory Board has been much impressed with the advances made in studies of laser irradiation uniformity. Also impressive are the measurements of thermal transport and the detailed agreement with theoretical predictions that have been carried out during the past year. It is important to note that calculations on the effects of 6-beam non-uniform irradiation in the blue, and reasonable confirmation by experiments could be of great political and scientific value in proceeding to 24-beam conversion. However, the Board knows of no single calculation or experiment that LLE can carry out that will convince the scientific community of the feasibility of direct-drive fusion.

In the past, the LLE has proven its strength in target design. The continuation of an imaginative program in target design for the 6- and 24-beam systems is strongly encouraged, with emphasis on target optimization including noncryogenic gas targets and high Z-shell targets. Because of Dr. McCrory's other commitments, a continued strong program in this area will require additional manpower.

HKF:pt(0821F

LLE should be commended for their fine publications record in refereed scientific journals. The work is well received by the scientific community. However, in our opinion LLE is not taking full advantage of semi-scientific and non-scientific publications, and the Board recommends that more attention be paid to publications in the latter.

#4 Applications

Due to reduced staffing, LLE has spent little effort in examining applications areas (breeding, synfuel research, etc.) or addressing reactor or engineering needs for a direct-drive system. Should we increase our activity in these areas? If so, what level of effort do you recommend?

For the current objectives of the program, significant involvement in applications seems unwarranted, given the limited resource base of the Laboratory. However, a certain amount of this activity is required to keep both LLE scientists and our sponsors aware of the long term strategies and potential applications of fusion. Do you believe our present support base could be enhanced by additional efforts in applications, particularly efforts involving joint research with public utilities or engineering firms?

Response: The Laser Fusion Feasibility Project (LFFP) at the LLE has as its primary mission and expertise the development of the body of science necessary to make Laser Fusion a practical reality. Therefore, it is incumbent on the staff of the LFFP to be aware of, and possibly participate in, any laser fusion reactor design exercises which are being or have been undertaken. Such activities will provide guidance to the scientific studies being carried out by the LFFP.

However, the Board does not feel it would be in the best interest of the Laboratory to undertake detailed application studies on its own. The Laboratory has neither the mission nor the resources to do so. If a potential sponsor indicates they wish to participate in the Project by concentrating on the application of Laser Fusion, the Board recommends the Laboratory insist the sponsor also make a substantial contribution to the science program of the LFFP. Otherwise, the sponsor could be a significant drain on the resources of the Laboratory.

The Board does feel, however, that it would be worthwhile for the LLE staff to pursue the potential application of the result of some of the non-fusion research. However, care must be taken to insure that these activities do not detract significantly from the scientific programs of the Laboratory.

Appendix D

UNIVERSITY OF ROCHESTER

Funding Status

FY 1984 and FY 1985

$ Thousands

FY 1984	UR REQUEST	DOE PROPOSED	ACTUAL DOE FUNDING	1980 DOE/UR CONTRACT FOR 1984
Operating Funds	5,800	5,200	5,700	6,700
Accelerated Conversion	1,400	--0--	--0--	--0--
Additional Tasks	--0--	--0--	180	--0--
Total Operation	7,200	5,200	5,880	6,700
Capital Funds	1,600	1,600	1,600	1,600
NLUF (Users)	500	300	500	1,000
	9,300	7,100	7,980	9,300
FY 1985				
Operating Funds	5,950	5,400		
Accelerated Conversion	700	--0--		
Additional Tasks	210	--0--		
Total Operations	6,860	5,400	NA	NA
Capital Funds	300	300		
NLUF (Users)	600	500		
	7,760	6,200		

Senator DOMENICI. Thank you both very much, and I'm sorry we had to be so abbreviated, but I think you know we have a genuine interest and we're going to do what we can to get the level funding up from where it was submitted by the administration. We think we need more, and we will try our best.

We stand in adjournment.

[Whereupon, at 11 a.m., the hearing was adjourned, subject to the call of the Chair.]

APPENDIX VI

Responses to Additional Questions

Department of Energy
Washington, D.C. 20585

MAY 3 1984

Honorable J. Bennett Johnston
United States Senate
Washington, D.C. 20510

Dear Senator Johnston:

With your April 23 letter we received five sets of questions for our response to be included in the printed record. One set of questions related to the April 5 hearing when the Director of Inertial Fusion, Richard L. Schriever, testified.

Enclosed are the answers to questions on inertial confinement fusion.

If you have any questions, please call Hank Edler or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

for Thomas H. Pretorius
Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Al Astrin

QUESTIONS BY
SENATOR JOHNSTON
FOR DOE

INERTIAL CONFINEMENT FUSION

Senator Johnston. Your FY 1985 request for inertial confinement fusion is $138 million, 19 percent below the FY 1984 appropriation of $169.7 million. What activities would you intend to curtail if Congress appropriates this lower amount of money? Explain the rationale for each cut.

Mr. Schriever. The difference includes the reduced final appropriation for PBFA II construction, which will be completed by early 1985. We are also requesting $3.1 million less in capital equipment, consistent with the reduction of $19.8 million in the request for operating expenses. At the requested budget level we would complete the carbon dioxide laser evaluation in mid-1985 rather than at the end of the year. The rationale for doing this is that ANTARES began operation at the end of 1983 and 18 months of experimentation may be sufficient to complete the data base we need for a program decision in 1987. If we get unanticipated results we will have to reconsider the ANTARES experimental schedule. We would operate NOVA on only a single shift basis when that facility begins operation early in 1985. The pulsed power program has made a diode selection for PBFA II ahead of schedule so a slight reduction is possible. The remaining laboratories, which support the glass laser experiments and pulsed power activities, will be slightly reduced in line with the reductions in those major programs.

Senator Johnston. When does DOE expect to achieve ignition, scientific breakeven, and the production of useful energy from inertial confinement fusion? What are the necessary steps to achieve this? Is this the first priority of the inertial confinement fusion program? If not, why not?

Mr. Schriever. The computer codes we use to model the complex processes involved in energy transport to and absorption in the fuel pellet can be used to predict the physical conditions for ignition and breakeven. These codes give such results when a megajoule or more of beam energy is efficiently absorbed in a fuel pellet and the fuel is stably compressed to a thousand to ten thousand times the density of solid hydrogen. The ANTARES, NOVA and PBFA II drivers should give us a good understanding of absorption efficiencies at long and short wavelengths of light and with light ions. NOVA experiments with targets that are hydrodynamically similar to the larger targets appropriate to an ignition driver will help answer uncertainties about this aspect of target design. We expect that we will by the end of the decade, perhaps earlier, be able to predict with considerable confidence the physical requirements for ignition and breakeven, and perhaps the potential for high gain targets that will be required for energy production. Hence, the first priority of our program plan is to complete these major facilities.

Our second priority has been to build a data base for experiments using these large facilities. The HELIOS experiments at Los Alamos had begun to accomplish this objective for long wavelength carbon dioxide laser light by mid-1983. The ANTARES laser is finishing the long wavelength laser evaluation we hope to complete by mid-1985. During the past year we have had good results from both NOVETTE at Livermore and from experiments using six beams of the Rochester OMEGA laser that have been converted to short wavelength operation. In the pulsed power program at Sandia, which is supported by Cornell and the Naval Research Laboratory, the choice of the appropriate diode for PBFA II has been made and lithium has been chosen as the light ion to be accelerated in that machine. These developments represent considerable progress toward building the data base that we need. Thus we have had considerable success in preparing for experiments on the larger machines.

Inertial fusion is an applied research program with important near-term applications to weapons physics and directed energy weapons research. Until we have established the feasibility of high energy gain and performed detailed engineering studies with the actual driver-pellet combination, we cannot confidently project a time when useful energy production might be accomplished. I believe it is important to establish feasibility and have energy production as an inertial fusion program goal, but neither the time required to engineer an energy producing system nor the time when fusion will be required as a national energy option can be established now.

Senator Johnston. When will the private sector likely support a significant share of the costs of inertial confinement fusion development? Has anyone from the electric utility industry shown any interest in inertial confinement fusion? Is so, please describe the nature of this interest.

Mr. Schriever. Electric utility companies now support inertial fusion through the program of the Electric Power Research Institute, which funds reactor design studies and some experimental work on engineering issues such as lithium blanket composition. In addition, significant amounts of private capital have gone to the University of Rochester and KMS Fusion, Inc., two of our glass laser experiments contractors.

Senator Johnson. Should this Committee judge the inertial confinement fusion program by its potential to contribute to U.S. energy supply or are there other reasons to support the program? What are the other reasons?

Mr. Schriever. It is important for this country to know what options it will have for energy sources in the next century, given various projections of supply and uncertainties such as undiscovered fossil fuel reserves and atmospheric changes that would arise from their use. We believe efforts to establish the feasibility of potentially large scale solutions such as fusion, which will not at this time attract adequate private funding because of the long-term payoff, are an appropriate Federal activity. Inertial fusion has near-term benefits in specific areas of nuclear weapons research, as well as in general enhancement of the capabilities of the weapons laboratories, that have been a major justification for the program from its beginning. These applications are in part already occurring and for the next decade or more can be expected to be realized at very low risk.

Senator Johnston. What are the expected design characteristics of an inertial confinement fusion power plant? Will such a plant produce primarily electricity, plutonium, heat, or some combination of these? Please explain. How far are we away from such a plant?

Design studies indicate that, assuming moderate to high gain, inertial fusion plants could be built at costs about equal to or up to twice as great as present fission plants. A major part of the plant, using steam heat to drive turbines in the case of an electrical generation plant, would be comparable to those of present fission or fossil fuel plants of the same energy rating. At moderate pellet energy gains plutonium enrichment would be economical, one inertial fusion plant producing fuel for a dozen or more fission plants. A possible first generation commercial plant could be a hybrid, producing enriched fissile material as well as electricity for its own use and for sale. By most estimates we are a generation from such plants based on magnetic fusion, and there is a general consensus that inertial fusion has a less mature scientific basis, and therefore would come later, than magnetic fusion.

Senator Johnston. Please summarize the work that has been done to address the engineering issues in the production of useful energy from inertial confinement fusion.

Mr. Schriever. Conceptual designs of power plants based on inertial fusion have been sought primarily to set boundaries for the driver efficiency and pellet gain issues and have on a limited basis addressed engineering issues. In the course of such studies many engineering issues have been raised but not resolved. These studies indicate that driver cost and complexity --e.g., number and disposition of beams, standoff of the driver from the fusion energy released, pulse rate, etc. -- will tend to dominate plant economics and many plant engineering considerations. Issues that can be addressed at least partly by calculations -- e.g., radioactivity that will be imparted to various materials, material lifetime under pulsed stresses -- have been studied but pulsed neutron sources are not yet available to verify most such calculations. Both DOE and the Electric Power Research Institute have funded studies comparing alternative driver systems and their impact on plant design.

Senator Johnston. Do you anticipate that there will be national security constraints on the commercial production of energy from inertial confinement fusion? What sorts of constraints?

Mr. Schriever. There are now classification constraints on certain weapons information used in inertial fusion research and development activities. Fusion breeders of fissile material or hybrid fissile breeder-electrical production fusion plants would face constraints of materials accountability similar to those for fission breeders or indeed, fission reactors. Tritium, now produced by the weapons complex primarily for weapons use, would be bred in a fusion plant for its own use and presumably would be controlled. If we assumed that inertial fusion power plants were available today, these are the kinds of constraints that would arise. Commercial production of energy from inertial fusion is unlikely to occur before we are well into the next century. Projecting these constraints into the future would involve considerations that lie outside fusion research and development.

Senator Johnston. What significant commitments to new facilities are anticipated in this program over the next several fiscal years? Please indicate the estimated cost of each such facility in dollars and as a percentage of the estimated budget for the inertial confinement fusion program.

Mr. Schriever. We do not now project any additional facilities for the inertial fusion program pending an evaluation, which we have planned to make in 1987, on the future of the program. The Department's guidance is to assume approximately level budgets in the outyears for planning purposes.

Senator Johnston. Compare progress that has been made in development of inertial confinement fusion as an energy source with the progress that needs to be made in the future if inertial confinement fusion is to be useful as an energy source.

Mr. Schriever. We need to understand the minimum energy required to drive a fuel pellet to ignition and high gain and, secondly, the form that energy must take in order that fusion energy will be produced efficiently and therefore economically. We have not yet shown experimentally that high gain is possible; hence this is the high-priority area we are working on. Efforts to reduce the uncertainties before us will produce new understanding and probably some surprises. Although we are unable to describe in detail an inertial fusion energy plant, we have increasingly exact knowledge about the target physics, much of which is classified because of the close ties to weapons physics. We have several competing driver approaches, no one of which is ready to be chosen today as the best solution to the known driver problems. Conversely, technical reviews of the program have failed to identify any "showstoppers" that would make further efforts not worthwhile.

Senator Johnston. Please list and describe the direct contributions of value to other DOE programs or to the economy generally from activities of the inertial confinement fusion program. Are other such contributions expected from the program in the future? What are they?

Mr. Schriever. The DOE weapons program benefits directly from data gained using inertial facilities to determine materials properties at extremely high densities and temperatures and theoretical understanding of hydrodynamic instabilities that cannot be gained by any other laboratory means. Inertial fusion research attracts and retains new talent in the laboratories in a field closely allied to weapons research and development. This benefit is incalculable. However, it can be observed that some of the ideas that have revived interest in the laboratories about advanced weapons concepts have arisen from inertial fusion researchers and can in part be investigated using inertial fusion resources of scientists and facilities. Inertial fusion systems operating in the physics regime of ignition and high gain are expected to open up new opportunities in weapons physics and in the simulation of nuclear effects. The specifics of present data and that expected to be gained in the future are classified.

Senator Johnston. How much money has been approriated for inertial confinement fusion in each year since the inertial confinement fusion program began? How much has been provided in each year to major contractors under the program (such as KMS Fusion, Inc.)? How much is projected to be spent on this program over the next five fiscal years?

Mr. Schriever. The following table gives the program funding by major program participant since inertial fusion began, and the Department of Energy's planning estimates for FY 1986-1989.

Inertial Fusion Program Funding
($ millions)

Fiscal Year	LLNL	LANL	Sandia	KMSF	U of R	NRL	Other	Operating Funding Total	Construction and Capital Equipment
1963	0.3							0.3	
1964	1.1						0.3	1.4	
1965	1.4							1.4	
1966	1.2							1.2	
1967	1.5							1.5	
1968	1.1		0.2					1.3	
1969	1.6		0.5				0.2	2.3	
1970	2.0	0.7	0.5				0.3	3.5	
1971	6.5	1.8	0.7			in other	1.9	10.9	0.4
1972	9.5	4.5	1.9			in other	2.3	18.2	1.9
1973	13.4	6.5	3.0			in other	3.0	25.9	10.2
1974	16.6	10.9	6.3			in other	7.4	41.2	8.2
1975	20.9	14.5	8.0	1.2		in other	1.0	45.6	19.5
1976	24.0	16.3	9.0	7.3		in other	5.0	61.6	18.1
1976T	7.0	4.8	2.5	2.4		in other	4.2	20.9	2.4
1977	31.1	21.5	10.2	10.0		1.8	5.7	80.3	31.6
1978	44.0	26.1	12.0	6.0	in other	2.8	14.1	105.0	25.6
1979	41.8	27.7	11.8	7.2	in other	2.5	13.9	104.9	39.2
1980	46.5	30.3	13.2	7.9	5.0	2.3	8.1	113.3	81.6
1981	56.8	38.9	16.7	9.3	5.4	2.8	10.6	140.5	69.1
1982	51.7	36.9	15.9	7.9	4.6	2.1	3.3	122.4	86.7
1983	56.1	41.8	19.5	10.5	6.1	2.9	3.1	140.0	49.8
1984	59.0	43.4	21.2	10.8	6.3	2.5	1.8	145.0	24.7
Request									
1985	55.5	30.5	19.8	10.2	5.9	2.3	0.8	125.0	13.0
Projections									
1986								158.0	15.0
1987								165.2	16.0
1988								172.6	17.0
1989								180.0	18.0
1990	DOE has not yet made a planning estimate for this year								

LLNL = Lawrence Livermore National Laboratory
LANL = Los Alamos National Laboratory
Sandia = Sandia National Laboratories, Albuquerque
KMSF = KMS Fusion, Inc.
U of R = University of Rochester
NRL = Naval Research Laboratory

APPENDIX VII

ADDITIONAL MATERIAL SUBMITTED FOR THE RECORD

STATEMENT

of

DR. RAMY A. SHANNY

PRESIDENT, INESCO, INC.

on the

MAGNETIC FUSION PROGRAM

of the

DEPARTMENT OF ENERGY FY 1985 AUTHORIZATION

before the

SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

Washington, D. C.
April 5, 1984

Mr. Chairman and Members of the Committee: It is an honor and a pleasure to appear before you today. I am Dr. Ramy Shanny, President of INESCO, Inc., a privately financed and soon to be a publicly traded company that has focused all of its efforts on the engineering development of commercial fusion power. Prior to joining INESCO, I was Director of the Plasma Physics Division of the Naval Research Lab. Today, I want to acquaint you with INESCO's accomplishments and their potential scientific and economic benefits for the nation's fusion program.

The objectives of both INESCO and the U.S. magnetic fusion program are to attain ignition and controlled burn. Both INESCO and the DOE program utilize the same principles of physics, but differ in their engineering and experimental approach. To date, no machine, either in the U.S. or abroad, has accomplished controlled burn. In the U.S., no machine presently exists, and none is under construction, that could attain this goal. However, accelerated development of INESCO's propriety technology will benefit the nation by moving toward this goal through enhancing the cost-effectiveness of fusion ignition technology.

The key to INESCO's activity has been the earliest possible attainment of commercial fusion power. Since 1981, INESCO has expended more than $15 million in pursuit of private development of small scale fusion tokamaks. INESCO's emphasis has been a classic engineering approach toward the development of commercial fusion power. We are not a research institution. Indeed, our designs are premised on the knowledge of plasma physics derived from the DOE and international tokamak research programs. In this effort, INESCO has assembled a "critical mass" team of highly skilled engineers to translate conceptual ideas into practical engineering designs.

INESCO has already designed a family of compact water-cooled high strength copper alloy tokamaks which should attain ignition, and allow for the study of controlled burn, at fusion power output in excess of a several hundred MWth. These machines are far smaller and much less expensive than any of the tokamaks being developed or contemplated in the current DOE program.

Two unique engineering features have characterized INESCO's work, each of which is critical to the success of our compact tokamak machines. First, we early recognized that the success of high-field small machines would depend strongly on the attainment of magnet coil materials strong enough to support the high fields desired. To this end, INESCO undertook a major effort in the development of improved copper alloys of high strength and high electrical conductivity. INESCO also developed inorganic insulators, which are radiation resistent, for use in these high field magnets. This work has been amazingly successful. These breakthroughs have overcome the critical hurdles that previously existed to the attainment of fusion burn in a compact tokamak.

The second important and unique feature of our work has been the development of a fully synergistic and integrated computerized systems design code for machine design over a wide range of parameters. It is the kind of detailed parametric design code traditionally used in the aerospace industry, and we believe it is the most advanced design tool of its type in the fusion field.

All of our machine designs will be able to reach fusion ignition conditions and sustained burn in a deuterium-tritium (D-T) plasma under the standard confinement scaling laws obtained in the DOE program. INESCO's sustained burn would generate several hundred MW of fusion power over a machine life of approximately 1000 hours. INESCO's machines will provide adequate burn time to understand the best design for a practical fusion reactor.

This INESCO has already accomplished. But it is now at a critical point in its history, when engineering design must turn to fabrication. Although practically all of our technology development has been financed privately, such private financing obviously involves high risk and long term pay off. As a result, construction of INESCO's ignition test machines that are financed solely with private funds will require long lead time.

However, a one year cost-shared private and government funded program would combine the best features of entrepreneurial skills and public support. For a very modest governmental investment, a cost-shared program would provide the nation with a key technology that could accelerate substantially the attainment of fusion power.

The modest federal investment INESCO seeks is $2.5 million to accelerate fabrication and testing of the high strength, high conductivity water cooled copper magnet coils that it has developed and designed with private funds. INESCO would continue to apply private financing toward this program.

This approach already has been recommended by the House Science and Technology Committee in its FY 1985 DOE authorization bill. Moreover, it has been recommended by HS&T as a part of the Administration proposed budget level in magnetic fusion for FY 1985, not as an add-on to that budget.

Following completion of the fabrication and testing of these magnet coils, INESCO will be able to proceed with its program of developing a central facility for the testing of inexpensive tokamak machines. This central facility will serve as the testing ground for the repetitive demonstration and testing of several machines over a range of potential design parameters. This approach will allow experimental optimization of plasma performance by testing a number of varied machines. Each of these tokamaks will cost less than $10 million. In this way, if one machine's design is unworkable, or fails for any reason, another machine will be available with an alternative design. By this means all of the relevant physics of fusion ignition and burn can be explored at modest cost and in a relatively short time. At the same time, we will have tested such a variety of designs that a pratical fusion reactor can then be constructed.

As you may know, the Soviet Union is working actively on a program that utilizes small copper coil tokamaks. The Soviet program is also an engineering design program that could lead to ignition within several years. However, the Soviet Union will not be able to achieve sustained burn for two reasons: first, they have not developed the high conductivity, high strength copper coils, insulator technology and fabrication techniques that INESCO has designed; and second, they lack the overall infrastructure of the USA.

Thus, if INESCO's development program is carried forward expeditiously, the U.S. is likely to achieve the breakthrough of a sustained fusion burn before the Soviet Union. Moreover, apart from the international benefits, if INESCO's program proceeds apace, the results of its contributions to high field tokamak engineering will be of significant value to the U.S. mainline program as it proceeds toward development and design of the world's first tokamak fusion reactor.

Thank you.

4/5/84

DEVELOPMENT OF 'ANEUTRONIC' NUCLEAR ENERGY

TESTIMONY
of

Dr. Bogdan C. Maglich, Chairman of United Sciences Inc.
(formerly Fusion Energy Corp/Aneutronix Inc.)
2118 Rockefeller Center, 1270 Avenue of the Americas,
New York, NY 10020

at the hearing of

The Energy Research & Development Subcommittee of the Committee on Energy and Natural Resources of the U.S. Senate on April 5, 1984

The Report on the "Energy & Water Development Appropriation Bill, 1984" of June 16, 1983 states:

> "To date, basic research in the fields of nuclear fission and fusion has largely overlooked the potential for aneutronic nuclear alternatives using light metals such as lithium, which produce no radioactive side-effects. The Committee recommends the Department give higher priority to this nonradioactive and nonproliferatory nuclear potential. The Department should allocate funds necessary to conduct a feasibility study to test the conditions necessary to produce a prototype aneutronic reactor, and to fully examine the theoretical principles of self-sustaining aneutronic energy." (98th congress, Senate Rep. No. 98-153, June 16, 1983).

At the Appropriation Conference, held on June 29, 1983 the following provision was agreed upon:

> "The Conferees agree that the administration shall consider including funding in the FY 1985 budget submission for aneutronic fusion activities, for consideration by the Congress." (98th Congress, H.R. Report No. 98-272, June 28, 1983).

On July 19, 1983, Dr. Alvin W. Trivelpiece, Director of the Office of Energy Research, U.S. Department of Energy wrote to me:

"The Department of Energy intends to make every effort to follow the conferees' suggested course of action and to give due consideration to future funding of aneutronic energy, based upon an evaluation of all the available evidence".

However, the DOE 1985 budget does not allocate a single dollar to aneutronic energy research.

The DOE's development of new nuclear energy sources is totally commited to demonstrating the highly neutronic DT fusion with one technology, the TOKAMAK. (D and T denote the fuel, a mixture of deuterium and tritium; TOKAMAK is a Russian acronym for a donut shaped chamber). The DT fusion research has made great progress over the past 30 years and the DOE's policy is to keep up the momentum by not allowing diversion of any funds from it to the competing ideas, even if these newer ideas are better. The concept of a Tokamak-based 'crash' program does not originate in USA but in USSR and dates back to 1973. However, the Soviet government killed its Tokamak program in 1975 and we started ours unbeknowingly in 1976, in a belief that it will be done in collaboration with the Russians. Unfortunately, the DT fusion is burdened, to a varying degree, with all the problems of the fission reactors: radioactive waste, weapon proliferaction potential, large size, large shielding, large heat pollution and enormous cost.

It has been said that discovery of an important need was almost as great a contribution as the invention itself. Whoever examines the scientific causes underlying the environmental, political and economic problems of nuclear energy, both fission and fusion, would undoubtedly conclude that what the society needs is nuclear energy without neutrons. We will refer to it as 'aneutronic' nuclear energy.

If one could design an aneutronic nuclear power reactor, such a reactor could never harm a human. If there is aneutronic nuclear fuel, it can never be converted into nuclear weapons. Neutrons, essential for nuclear weapons, are atomic-age villains in civilian applications of nuclear energy. They convert natural uranium into the atomic weapon fuel, plutonium. They can penetrate up to 16 feet of steel and cause structural damage in the toughest of materials, make them radioactive, brittle and accident prone. Present day reactors must be enclosed by thick, concrete shielding, many times the weight of the reactor itself; thus, conventional fission plants are large, uneconomical and therefore unsuitable for decentralized use. They also would not be feasible for mobile or airborne use.

Without neutrons, nuclear explosion or even a 'runaway' accident are not possible; massive shielding is unnecessary; the ability to breed and proliferate nuclear weapons does not exist; there is a potential to produce electricity directly, without heat; and a small, compact lightweight reactor system becomes conceivable.

The existence of aneutronic nuclear reactions, has been known for 52 years, but, mainly because of the lack of miliatry interest, no major effort was made to overcome technical problems which stood in the way of utilizing them as power sources. These reactions are initiated by protons and it was believed that there could be no proton chain reaction-thus, no bomb. The first aneutronic reaction was discovered by Cockroft and Walton in 1932 in Cambridge, England. They bombarded the lithium nucleus with protons and split it into two helium nuclei with a release of a large amount of energy. The energy released per fuel weight was twice as much as that released in the fission of uranium.

The aneutronic reactions can be described as the "splitting of light nuclei by light nuclei", or simply "light fission". The metals used are lithium, beryllium and boron (mined as 'borax'). The process is different from either fission or DT fusion, but since they have more similarities with fusion, they have been called (wrongly) advanced-fuel fusion.

In 1966, Rand McNally has shown that proton chain reactions are possible.

United Sciences Inc., was founded in 1972 (as Fusion Energy Corp.,) to pursue aneutronic research. To date $14 million of private funds have been spent.

The research program is being carried out at the Aneutronic Energy laboratory of United Sciences at Princeton, NJ, in association with a research consortium consisting of Polytechnic Institute of New York, University of Buenos Aires and the University of Graz, Austria. Four laboratory models of the aneutronic reactor named "migma cell" have been built and four stages of a five-stage research and demonstration program had been completed. See Diagram of progress (next page).

The next--and the last--research stage, Stage 5, will bring migma into ~~enter~~ the reactor regime i.e. reach or exceed the energy breakeven conditions. It is a 4 year $30 million program. However, if we could use the newly built prototype RFQ accelerator at Los Alamos, it would become a $10 million 2-year program. Prior to embarking into the last stage experiment, we need a one to two-year teoretical and experimental feasibility study program which would cost $1.5 - $2 million/year.

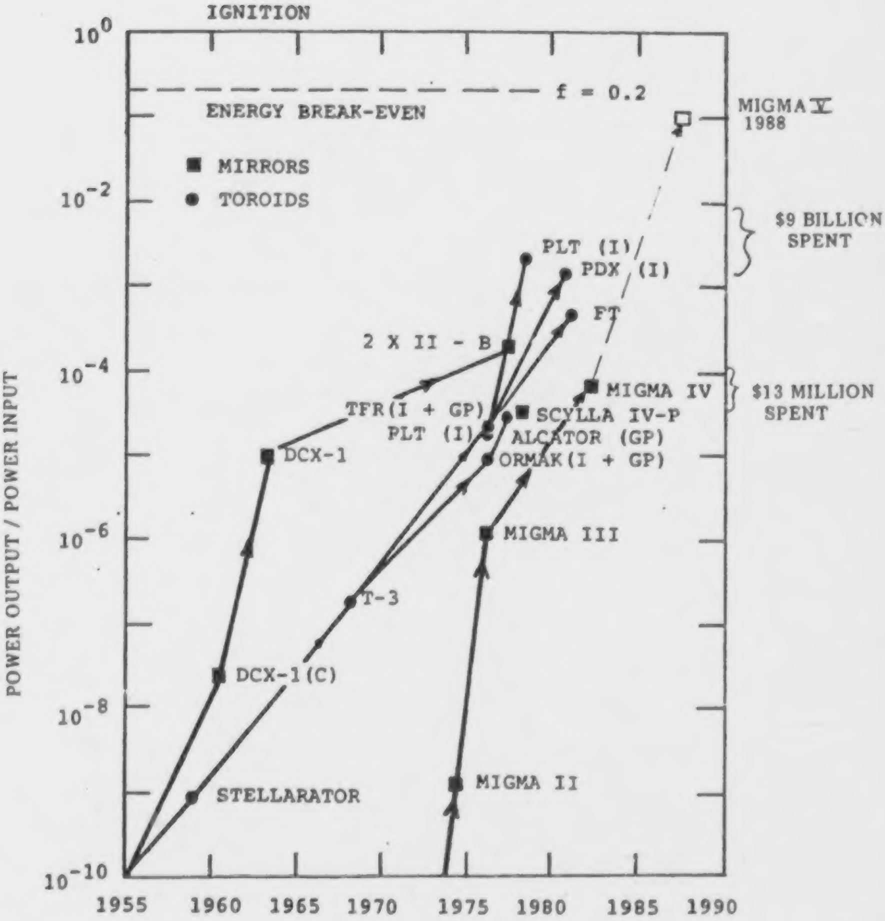
We respectfully request the subcommittee to add-on $1.5 million for aneutronic energy theoretical and experimental feasibility studies to the DOE appropriation for FY 1985.

Summing up the aneutronic nuclear processes release more energy per fuel weight than nuclear fission, yet they are:

- non-radioactive
- accident-proof

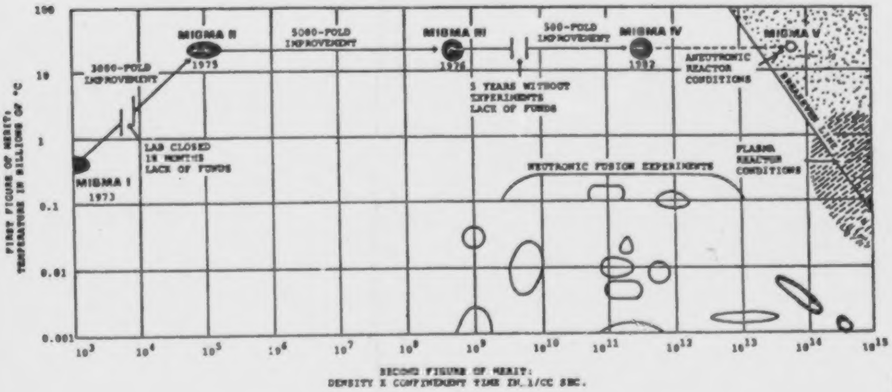
- proliferation-proof -- cannot breed nuclear weapons
- much reduced source of heat rejection to the environment, compared with oil, coal or conventional nuclear plants -- because of direct conversion of energy
- suitable for small size power plants (mass produced units could be stacked into any size plant)
- projected to have low capital and fuel cost

Since radioactivity, runaway-accidents, waste disposal, weapon proliferation potential, heat pollution, large plant size, high capital and fuel cost have been the main areas of controversy for nuclear fission plants being used today, as well as the potential nuclear fusion plants of the current governmental research programs, aneutronic energy offers a radically alternative form of nuclear power. The U.S. utilites find DT fusion unacceptable for power plants and are against the early construction of DT fusion reactors. States E.L. Draper of Gulf States Utilities: "their construction will discourage development of advanced fuel cycle (aneutronic) fusion devices which offer more promise for widespread practical application". (Bull. American Physical Society, Washington Meeting, 1984).



PROGRESS OF DT FUSION VS. ANEUTRONIC

Comparative Progress of Migma (Aneutronic) Experiments (1973-82) with Current Status of Neutronic Fusion Experiments



There are two generally accepted 'criteria of merit' used to measure progress toward proof-of-principle in nuclear fusion experiments, both neutronic and aneutronic.

The horizontal axis shows ion confinement densities (how compressed the fuel is) multiplied by time of confinement (how long the compressed fuel can be held together).

The vertical axis shows temperature in degrees Celsius. In the case of neutronic fusion experiments, the temperature is typically hundreds of millions of degrees Celsius, but in the case of Migma (aneutronic) research, the typical temperature is two orders of magnitude higher (tens of billions of degrees Celsius).

While Migma achieved its needed temperature goal equivalent to the Migma II experiment in 1975 (30 billion degrees Celsius equivalent), its further goals had still to be reached on the horizontal axis (density x confinement time) and the progress to date is noted.

Net energy production is projected for conditions to the right of the Breakeven Line.

The Migma V experiment - the last stage - is to increase the product another 100 times. This would put migma into the energy producing regime, thus demonstrating scientific feasibility of aneutronic nuclear energy.

United States Senate
WASHINGTON, D.C. 20510

APR 9

April 5, 1984

OFFICE OF
SEN
PETE V.
WASHIN

The Honorable Pete V. Domenici
United States Senate
Washington, D.C. 20510

Dear Pete:

We wish to comment jointly on the essentiality of the role being carried out by the University of Rochester's Laboratory for Laser Energetics in the National Inertial Fusion Program. Further, we wish to remark on the adverse consequences of the proposed Department of Energy Inertial Fusion budget and specifically how that proposed budget will not allow the Laboratory effectively to carry out its mission.

The Laboratory for Laser Energetics fulfills a vital mission in this Nation's Inertial Fusion Program by providing laser-matter interaction data, capsule physics, diagnostics development, and laser-optical engineering, the under-pinning of DOE's Defense Programs in glass lasers. Rochester has made numerous and critical contributions to high-energy density research, laser development, and optical engineering. The Laboratory is particularly known for its breakthrough in frequency conversion which greatly enhances the effectiveness of all glass lasers used in inertial fusion research.

The National Laser User's Facility (NLUF) at LLE is a major national resource providing the only open United States high-power laser laboratory available to U.S. researchers. Moreover, hundreds of students have been trained at LLE on state-of-the-art high-power lasers in the fields of plasma physics, optical engineering, materials science, and other disciplines needed to meet some of this nation's critical requirements. This training is vital to the future of U.S. technology, not only in inertial fusion but for our national defense capabilities in general. Thirty-seven (37) of these students have completed Ph.D. research at LLE and twenty-one (21) are currently performing doctoral research. Graduates of the Rochester program are now making significant contributions at all major United States laser fusion laboratories.

The Laboratory has met every program milestone in its five-year DOE operations contract, a remarkable record of achievement. This record was accomplished in spite of significant funding shortfalls from the Department of Energy. A major highlight of the FY83 program was the completion of the conversion of the first six beams of the OMEGA laser system. The initial six beam conversion and experiments were completed on-time and within budget. All the performance criteria established by DOE were met or exceeded (Attachment A). An additional six beams are scheduled for conversion in 1984. Data essential to meet the National Program plan for a 1987 assessment of inertial fusion require the conversion of all OMEGA beams, 24, to the ultraviolet. Only with the complete conversion of the 24 beam system will it be possible to conduct the spherically symmetric target implosion experiments which are necessary to define the viability of inertial confinement fusion by 1987, a DOE goal.

The proposed $6.2 million DOE budget in LLE in FY85 (see Attachment B) will not allow for complete conversion of the system and effective use of the laser. Rochester has already sacrificed staff (25% reduction-in-force) in FY82 in order to initiate the OMEGA conversion and keep operations on-going. The proposed DOE budget may require still additional reductions but if that is necessary it may instead require the termination of activities for there is no more cutting without vital harm to the program. As proposed, the budget would have insufficient funds to retain the engineers to complete the OMEGA conversion, or the scientists required to plan and execute the experiments, or the technicians required to operate the NLUF.

The complete conversion of the OMEGA system, the final 12 of the total 24 beams, will require an additional $1.4 million out of a required total appropriation of $7.76 million. Note that the requested total appropriation is less than that for FY84. We urge that $7.76 million be designated for Rochester for FY85 for inertial fusion research in your decision and reporting process. Had Rochester obtained the full funding originally agreed to in the contract with DOE, it now would be conducting 24 beam ultraviolet experiments in addition to training significantly greater numbers of students and conducting more NLUF experiments.

In summary, the University of Rochester's Laboratory for Laser Energetics is on the threshold of attaining the capabilities required to carry out the experiments mandated by the 1987 National Program milestones. The Laboratory has an exceptional record of technical innovation and financial integrity. It would be inappropriate and unwise to preclude progress in the Rochester program after the program has demonstrated a consistent record of accomplishments, especially at this critical time when DOE is preparing to make a decision on the future of inertial fusion. We urge that the Rochester program be authorized $7.76 million in FY85

Attached for your information is a summary of LLE's 1983 activities (Attachment C) and a copy of the report from the Research Advisory Board on LLE's program (Attachment D). We hope you will find this information useful and we look forward to working with you on this and other issues of importance to New York and to this nation.

Sincerely,

Alfonse D'Amato

Daniel Patrick Moynihan
United States Senator

Alfonse D'Amato
United States Senator

Department of Energy
Nevada Operations Office
P. O. Box 14100
Las Vegas, NV 89114-4100

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DIRECTOR'S OFFICE

NOV 2 9 1983

Dr. Robert McCrory, Director
Laboratory for Laser Energetics
University of Rochester
250 East River Road
Rochester, New York 14623

OMEGA CONVERSION

On November 2, 1984, the OMEGA Performance Review Group met to evaluate OMEGA 3ω performance of the first six beamlines and to determine if the performance criteria established on June 1, 1983, had been satisfied. The chairman of the Group subsequently reported the results of that review and the Group's recommendation to the Director, Office of Inertial Fusion (OIF).

Based on an assessment of the data presented, the Director, OIF, has concurred with the findings of the Review Group that all performance criteria had been met.

You are therefore authorized to proceed with the conversion to blue of an additional six beams during FY 1984.

Members of the Review Group and the Director commend you and your staff for the excellence of your presentation, and for your dedicated efforts during the preceeding months in completing the conversion and testing of the first six beams in such a timely manner.

Rex B Purcell

Rex B. Purcell
General Engineer
Resource Management & Budget Division

RMBD:RBP-865

UNIVERSITY OF ROCHESTER

Funding Status

FY 1984 and FY 1985

$ Thousands

FY 1984	UR REQUEST	DOE PROPOSED	ACTUAL DOE FUNDING	1980 DOE/UR CONTRACT FOR 1984
Operating Funds	5,800	5,200	5,700	6,700
Accelerated Conversion	1,400	--0--	--0--	--0--
Additional Tasks	--0--	--0--	180	--0--
Total Operation	7,200	5,200	5,880	6,700
Capital Funds	1,600	1,600	1,600	1,600
NLUF (Users)	500	300	500	1,000
	9,300	7,100	7,980	9,300
FY 1985				
Operating Funds	5,950	5,400		
Accelerated Conversion	700	--0--		
Additional Tasks	210	--0--		
Total Operations	6,860	5,400	NA	NA
Capital Funds	300	300		
NLUF (Users)	600	500		
	7,760	6,200		

Summary of Research Activities - 1983
Laboratory for Laser Energetics
University of Rochester

The fiscal year ending September 1983 (FY 83) was a productive one for the Laboratory for Laser Energetics (LLE). Progress in inertial confinement fusion was made by demonstrating the advantages of short-wavelength lasers for efficient coupling to fusion targets. Experiments at LLE with both the 24-beam, 1054-nm OMEGA facility and the single-beam, 351-nm, Glass Development Laser (GDL) system have concentrated on the physics of coronal coupling, energy transport and uniformity for short-wavelength, direct-drive laser fusion.

A major highlight was the completion, in the final quarter of the fiscal year, of the conversion of the first six 351-nm beams of the OMEGA system. An ultraviolet energy of over 300 J on target was achieved, and higher energies are expected as we gain confidence in the performance of the system. In support of this work, LLE developed a single monolithic frequency-conversion cell, similar to that developed at Livermore. The design takes advantage of the highly efficient frequency-tripling scheme originated at LLE, and uses a new index-matching liquid whose favorable damage-resistant properties were first established at LLE. The conversion cells installed on OMEGA have performed consistently for hundreds of shots, and have generated 351-nm energies in close agreement with theoretical predictions.

The laser facility operations continued at a high level. During FY83 the GDL and OMEGA facilities provided totals of 1724 and 1182 shots, respectively. GDL delivered 894 target shots in support of the various experimental programs, 422 shots for the damage-test facility and 408 miscellaneous system shots. OMEGA delivered 384 target shots in support of the drive uniformity, interaction physics, National Laser Users Facility (NLUF) and x-ray laser programs, and 798 shots for various system purposes including driver alignment, beamline calibration and UV conversion.

The Theoretical Division developed a new analysis of illumination uniformity on spherical targets using a spherical-harmonic decomposition of the energy deposition pattern of overlapping beams. Irradiation uniformity is estimated using this analysis from measured beam equivalent-target-plane profiles. The OMEGA system has been found to have no nonuniformities greater than approximately six percent in low-order spherical harmonic modes. Beam profile improvements demonstrated on GDL, together with a reduction of the OMEGA beam energy variance, are expected to yield irradiation nonuniformities a factor of three lower. The resulting irradiation symmetry will be close to that required for high-gain target implosions.

The Laboratory has now completed an extensive series of thermal transport experiments at 1054 nm on OMEGA. Thermal transport in spherical geometry has been found to differ markedly from transport in comparable single-beam target irradiation experiments, and cannot be described in terms of a simple transport model, whether flux-inhibited or uninhibited. Deep energy deposition in spherical irradiation (by electrons in the tail of the thermal velocity distribution) has been found to lead to a temperature profile which is not as steep as predicted by either transport model. Target implosion experiments have showed higher core temperatures than predicted by a flux-inhibited model, but lower densities than predicted by an unhibited-flux model. Further experiments are planned to substantiate some of the conclusions drawn on the basis of this campaign, and theoretical work on the development of improved transport models is currently in progress.

Harmonic and sub-harmonic emission measurements were made on spherical targets on OMEGA, providing important information about instability phenomena occurring in the underdense plasma corona. Emissions of $2\omega_0$ and $5\omega_0/2$ from the quarter-critical density region were observed for the first time. A systematic study of the spectral features of these emissions led to an improved understanding of their potential use as underdense plasma diagnostics. These emissions are also signatures of parametric processes which can lead to the generation of very energetic "superhot" electrons, and for this reason investigations of their dependence on wavelength, intensity and geometry were made on both GDL and OMEGA. Delineations between Stimulated Raman Scattering and the two-plasmon decay ($2\omega_p$) instability were made with 351-nm radiation in planar geometry, and, in spherical geometry, the $2\omega_p$ instability was identified as the principal generator of superhot electrons in 1054-nm experiments. Another important outcome of this work was the development of a new theory of the $2\omega_p$ instability; the plasma waves produced by this instability are also responsible for many of the harmonic emissions.

Detailed information on the production of energetic electrons were obtained from measurements on GDL of the continuum x-ray spectra produced by IR- and UV-generated laser plasmas. The spectra obtained from the 351-nm experiments lack a component ascribable to "hot" electrons produced by resonance absorption, in strong contrast to the spectra obtained using 1054-nm radiation. This result is important because it leads to the expectation that spherically irradiated targets at 351 nm will experience minimal electron preheat. Additionally, these spectra show a high-energy component at both wavelengths, due to a superhot electron distribution. On the basis of the correlation between intensity scaling of the superhot energy and the harmonic light emission from the target, the superhot distribution is attributable to the presence of the $2\omega_p$ instability, which appears to exceed threshold intensities at approximately $2\text{x}10^{14}$ W/cm^2 and saturate above $4\text{x}10^{14}$ W/cm^2. While the measured level of superhot electron production (less than 10^{-3} of the absorbed energy) does not present a serious preheat problem for laser-driven fusion targets, the targets and scale lengths used in these experiments are too small to allow the present results to be generalized to reactor-sized targets. . It is important that future research should continue to monitor the superhot electron production in the underdense plasma when increased energies, and correspondingly greater intensity-length products, become available.

LLE significantly advanced the numbers and types of diagnostics available for measuring laser-fusion target interaction events. The diagnosis of laser-produced plasmas makes special and demanding requirements of x-ray spectroscopic techniques. During FY 1983 two x-ray instruments incorporating free-standing x-ray transmission gratings to provide broadband spectral resolution were developed. The first, a spectrally dispersive microscope, was used to obtain two-dimensional monochromatic spatial images of laser-fusion targets. This instrument has been used successfully to measure the spatial extent of the core of an imploded glass microballoon containing mixtures of deuterium and argon. The second instrument, a transmission-grating streak spectrograph, was developed and used to measure the target x-ray emission with simultaneous temporal and spectral resolution. Additionally, x-ray crystal devices were used in three new x-ray diagnostic developments: a Von Hamos x-ray spectrograph was developed and used to obtain measurements of ionic spectral lines in the 12-14-keV energy range; mosaic crystals were used in a geometry which yields both high sensitivity and resolution; and, finally, two-dimensional achromatic imaging demonstrated 10-μm resolution using Laue crystal diffraction.

Substantial progress was made in the theoretical understanding of the physics of high-energy-density plasmas. We investigated the effects of magnetic fields on electron heat transport in fusion targets, and elucidated the relationship between flux-limiting and magnetic-field-induced transport inhibition using a simple model which describes the transition between these two regimes in a physically reasonable way. For parameters corresponding to typical 1054-nm interaction experiments the theory shows that strong inhibition should occur for fields as small as 100 kilogauss, roughly an order of magnitude smaller than the megagauss fields which have been observed. At shorter laser wavelengths the plasmas are more collisional, and magnetic field effects are expected to be less important.

The LLE target fabrication group continued to enhance its ability to fabricate and characterize targets. One significant development is an improved interferometric technique, using a rotational-shearing interferometer, for the characterization of non-concentricity in transparent inertial-fusion targets. This technique offers distinct advantages for characterizing transparent targets; in particular, defects not easily visible using conventional target characterization techniques can be readily recognized, and the sensitivity of the instrument is not dependent on the target shell thickness. During the year the group has also investigated two polymeric materials for incorporating high-Z metallic elements into ablation layers. Sulfonated polystyrene neutralized with various alkali and alkaline-earth metals has been coated onto glass microballoons by solution dipping, producing an atomic-scale dispersion of the metal and the polymer with an extremely smooth surface. A metal-colloid-seeded polymer has also been coated by solution dipping. Although a homogeneous dispersion of metal is not achieved, metal colloids are dispersed as small particles of size of the order of 50 Å. This technique has the particular advantage that almost any metallic element can be used for the colloid. In another development, the drill-fill-and-plug target fabrication capability has been extended and improved, with the result that the mass perturbation caused by the plug has been reduced by at least two orders of magnitude. This increased target uniformity should contribute significantly to the success of high-compression implosion experiments planned for the future.

In our advanced technology areas, our technique for time-resolving electrical signals with sub-picosecond resolution, based on the Pockels effect induced in a traveling-wave electro-optic modulator, demonstrated an unprecedented bandwidth of 1 THz for electronic sampling. We expect this technique to be of importance in the study of laser-semiconductor interactions, in the propagation of electrical pulses, and in the characterization of ultra-fast electronic components. A second sampling technique has been developed which uses electron pulses rather than optical pulses to interrogate an unknown electrical signal. This new technique, "electron-optic sampling," samples electrical signals directly by probing their electric fields with electrons. The temporal resolution is currently around 35 ps, but a resolution of a few picoseconds appears possible in the near future.

Work continued on the LLE picosecond biophysics facility, in collaboration with outside users; here the energy transitions and deformations of photosensitive biomolecules are studied through observations of their fluorescent responses on very short timescales. Research this year included studies of the primary processes of photosynthesis using spinach chloroplasts, and investigations of large-scale structural changes occurring in the macromolecules DNA and HSA (human serum albumin).

LLE is developing laser-driven x-ray sources as a potent analytic tool to address a broad range of scientific and technological problems by extending our capabilities for time-resolved measurements on bulk structures. We used the GDL x-ray diffraction facility to obtain results on the time-resolved x-ray diffraction patterns from photostimulated biological systems such as *Halobacterium halobium*, sarcoplasmic reticulum, and dipalmitoyl lecithin.

The GDL facility was also used to obtain the first successful demonstration of a single-shot sub-micron-resolution x-ray lithograph using a laser-produced plasma as an x-ray source. The favorable exposure characteristics achieved make the laser-produced x-ray source promising for sub-micron lithography.

A collaborative experiment with Lawrence Livermore National Laboratory (LLNL) was conducted in order to investigate a laser-pumped photoabsorption x-ray laser. Eight beams of OMEGA, configured to produce a line focus, were used to irradiate an x-ray flashlamp target. The soft x rays produced in this interaction cause a rapid photoionization of Ne I to Ne II, creating a transient population inversion between the 2p and 2s states of Ne II. In this experiment a large number of new diagnostics were successfully activated and new methods were developed for target and beam alignment. We anticipate future experiments to investigate further the performance and potential of this approach towards the development of laboratory x-ray lasers.

In the LLE optical materials group, progress was made in several areas. In the key area of materials damage, it was demonstrated that sub-micron impurities in optical coatings can be detected using our photothermal-deflection microscopy system. In the future, research will be focused on identifying the exact nature of these damage-causing impurities; optical coatings of increased damage resistance will then be obtained by controlling impurities in the manufacturing processes. The group also developed and successfully tested liquid-crystal devices such as laser-blocking notch filters. Optical elements which exhibit low transmittance at a specific laser wavelength, and high transmittance at other wavelengths, are required to filter optical radiation incident on diagnostics or imaging systems; additionally, laser goggles for eye protection of personnel constitutes another area where these filters are useful. Research is continuing to determine the factors which limit the use of liquid crystals as notch filters over the entire optical spectrum.

The National Laser Users Facility, a unique national resource, enjoyed a successful year. User experiments conducted during this year (368 target shots) are summarized in the table below:

Table I

NATIONAL LASER USERS FACILITY

FY 1983 SUMMARY

Principal Investigator	Affiliations	Experiment	Number of Shots
Prof. F. Chen	UCLA & Yale U.	Plasma Instabilities	105
Prof. J. K. Blasie Prof. L. Herbette	U. of Pennsylvania U. of Connecticut	Biophysics	77
Dr. R. Elton	Naval Research Laboratory	X-Ray Laser	25
Dr. J. Forsyth	U. of Rochester	Biophysics	107
Dr. U. Feldman	Naval Research Laboratory	EUV Spectroscopy	32
Prof. H. Griem	U. of Maryland	Line Shifts	15
Prof. G. Miley	U. of Illinois	Particle Energy Loss	5
Dr. B. Yaakobi	U. of Rochester	X-Ray Diagnostics	2

In addition to its research mission, the Laboratory continues to maintain an important role in student training. During FY83, twenty-one Ph.D. thesis projects were in progress. In the Department of Mechanical Engineering, several students are investigating basic phemonena in laser-produced plasmas. One theoretical project concerns the $2\omega_p$ and Raman instabilities at oblique angles of incidence; an understanding of the scaling of these parametric processes is required for success in direct-drive laser fusion. Other students are investigating thermal transport, hydrodynamic efficiency and time-dependent ionization phenomena. In the Department of Physics and Astronomy, a student is investigating hot-electron behavior - a regime currently of interest to the semiconductor industry. Students and faculty from the Institute of Optics are investigating picosecond electro-optical sampling techniques, synchronous amplification of subpicosecond pulses, level inversions in laser-produced plasmas, and a variety of other basic laser-matter research areas. In the Department of Electrical Engineering, one student is investigating the propagation of electromagnetic waves in strip lines. This thesis may result in the development of a successful pulse-shaping technique for high-power fusion lasers.

Looking to the future, additional OMEGA beamlines will be converted for 351-nm operation. Based on our experience with the first six frequency-converted beams, we project energies of around 2 kJ to be available for experiments when all twenty-four beams are operational in the UV. We then expect to perform significant spherically symmetric ablative target-implosion experiments, which will help to define the conditions necessary for establishing the scientific feasibility of inertial confinement fusion. The demonstrated high repetition rate and system reliability of OMEGA give us confidence that the LLE facility will continue to be a valuable resource both for the National inertial fusion program and for other users of the system.

Robert L. McCrory, Jr.
DIRECTOR
Laboratory for Laser Energetics
University of Rochester

Bechtel Group, Inc.

Fifty Beale Street
San Francisco, California
Mail Address P.O. Box 3965 San Francisco, CA

Page 1 of 6

PRESIDENT'S OFF

JUL 25 1983

July 19, 1983

Dr. Robert L. Sproull, President
University of Rochester
Rochester, NY 14627

Dear President Sproull,

Please excuse the delay in getting you a response from the Research Advisory Board for the Laboratory for Laser Energetics. We had an excellent review of the program on May 31 and June 1, 1983 and, as before, we were most impressed with what we saw and heard. Specific answers to posed questions are provided in the attachment, but there are several comments the Board encouraged me to pass back to you.

We continue to be impressed by the high calibre of the LLE's performance. For the size of the effort and the resources with which they work, LLE is making an outstanding contribution. It is also refreshing to view the energetic, competent beginnings by the new Director. Your success in choosing such individuals is to be commended.

The LLE is the only US laboratory with a credible direct drive program. While we are certain that you understand this, others may not, and therefore it may be important to state here.

Finally, the technical work performed during the past year certainly demonstrates that it may be possible to provide adequate uniformity over the target to directly drive imploding targets.

We enjoyed our visit, the hospitality shown us all, and we thank you for the opportunity to review an exciting program.

Very truly yours,

HKForsen

Harold K. Forsen, Chairman
For the Research Advisory Board

HKF:pt
Attachment
cc: J.F.Barnes
G. Bekefi
J.M.Burger
R.W.Goodrich
H.Hurwitz,Jr.
M.N.Rosenbluth
I.L.White
J.Wilson

Bechtel Power Corporation Bechtel Petroleum, Inc Bechtel Civil & Minerals, Inc
Principal Operating Companies of Bechtel Group Inc

RESEARCH ADVISORY BOARD

Dr. Harold K. Forsen, Chairman

1 June 1983

Mr. Robert L. Sproull
President
UNIVERSITY OF ROCHESTER
Rochester, NY 14627

Dear President Sproull:

The Research Advisory Board for the Laboratory for Laser Energetics met on June 1, 1983 to review progress in the program. A number of initial conclusions were formed which we would like to forward for your consideration and use.

The Board concurs with the Laboratory management's difficult decision to effect staff reductions in order to proceed with conversion of the OMEGA system to BLUE light operation. We strongly encourage efforts to secure sufficient funding to permit timely conversion of all twenty-four (24) beams to proceed.

Research activities leading to the understanding of irradiation and drive uniformity of symmetric targets continues to be of a very high caliber with the theory and experimental programs well integrated. Similar comments can be made about the work going on in hydrodynamic stability and target fabrication requirements for stable and symmetric implosions. It is particularly encouraging to see that the uniformity requirements for direct-drive laser fusion are being addressed in a very scientific manner, so that quantitative criteria for the laser and focussing are being established. The beam uniformity achieved is impressive. These result give increasing confidence that direct-drive will be successful. This work appears to be well on track and at the forefront of research in laser fusion.

We were also favorably impressed with the broader research program in x-ray lasers, microstructures analysis, picosecond research, materials, and the applications in which these technologies may be used. Expanded work in these and other appropriate areas are to be broadly encouraged.

The high caliber of the staff continues to be impressive. We are pleased that their spirit and dedication to the objective of the program remains high. Involvement of graduate students to further these goals and to provide researchers for further investigation into these important areas is also encouraging and should be expanded.

Finally, a successful and timely search for a new director has been concluded with the selection of Dr. Robert L. McCrory, who is a knowledgeable, dynamic scientist, and should be able to provide the cohesive and stimulating leadership that has characterized this program in the past.

You should feel very proud of this unique national program of university research. A response to specific questions posed to the Board will be forthcoming, but should a need arise for additional input, please free to call any of us.

Sincerely,

HK Forsen

Harold K. Forsen
for the Committee

HKF/bla

UNIVERSITY OF ROCHESTER
LABORATORY FOR LASER ENERGETICS
RESEARCH ADVISORY BOARD MEETING
May 31, 1983

QUESTIONS FOR CONSIDERATION AND RESPONSE

#1 Advanced Research

The portion of LLE efforts spent on non-fusion, high-technology research and development, such as micro-structure analysis, high-speed electronics, and various aspects of biotechnology, has been steadily growing in spite of declining LLE funding. Do you believe the balance between the Laboratory's inertial fusion program and these other programs is correct?

Presently several scientists at LLE are seeking additional funding for some of these non-fusion areas. Potentially, this activity could bring significant positive support to the laboratory. Can the committee provide suggestions for extra-program support possibilities?

Response: The Board was impressed with the research in non-fusion areas and feels that such work is essential, as it will provide a broad scientific base on which to build the fusion work and will therefore have a synergistic effect. In addition, this work is in general more appropriate for student research than is the fusion work, in that a student is more likely to find a project that can be pursued individually for a thesis in this area. We see a higher probability of finding financial support in the non-fusion areas, which is a further reason for continuing such work. We caution, however, that, although the Board would like to see more effort in the non-fusion areas, we do not want it to be at the expense of fusion research.

With regard to finding additional funds, the Board recommends that a search be made for likely customers of the new technologies. The microstructure analysis and x-ray work is of interest to the solid-state community, and sources of funding from this community should be sought. Since an x-ray light source is a competitor for synchrotron x-ray generation, the customers of synchrotrons should be contacted. Synchrotrons have plenty of users, and it should be possible to attract some if an appropriate user x-ray facility could be created. Strong interest is developing in the possibility of laser acceleration of particles. There are several possible applications, from research to industrial, to weapons (creating the possibility of DOD funds). This combination of high power lasers and plasma physics is very appropriate for LLE.

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#2 Laser Fusion Program Objectives

In view of the general state of fusion research, do you believe that the objectives of the LLE laser fusion program are appropriate? In view of the current and probable future resources available to LLE, do you believe that the objectives of the LLE laser fusion program are realistic?

Response: The LLE program on the direct drive approach to fusion is appropriately and realistically structured towards establishing the basic physics needed to determine the feasibility of this concept. This broad based emphasis on carefully investigating the various parameters of this concept is preferable to a more narrowly structured effort aimed at demonstrating ignition at as early a date as possible. The conversion of the OMEGA laser to blue light is being aggressively pursued, and the Board continues to encourage this emphasis with the objective of implementation of the full 24-beam system as rapidly as funds can be secured. These funding objectives are within the reach of the program and should continue to be pursued vigorously.

#3 Direct-Drive Laser Fusion Demonstration

Is there a particular calculation or experiment that LLE can carry out that could convince the scientific community of the feasibility of the direct-drive approach to laser fusion? Is the Laboratory effective in presenting scientific results to the public and to the sponsors?

Response: The Research Advisory Board has been much impressed with the advances made in studies of laser irradiation uniformity. Also impressive are the measurements of thermal transport and the detailed agreement with theoretical predictions that have been carried out during the past year. It is important to note that calculations on the effects of 6-beam nonuniform irradiation in the blue, and reasonable confirmation by experiments could be of great political and scientific value in proceeding to 24-beam conversion. However, the Board knows of no single calculation or experiment that LLE can carry out that will convince the scientific community of the feasibility of direct-drive fusion.

In the past, the LLE has proven its strength in target design. The continuation of an imaginative program in target design for the 6- and 24-beam systems is strongly encouraged, with emphasis on target optimization including noncryogenic gas targets and high Z-shell targets. Because of Dr. McCrory's other commitments, a continued strong program in this area will require additional manpower.

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LLE should be commended for their fine publications record in refereed scientific journals. The work is well received by the scientific community. However, in our opinion LLE is not taking full advantage of semi-scientific and non-scientific publications, and the Board recommends that more attention be paid to publications in the latter.

#4 Applications

Due to reduced staffing, LLE has spent little effort in examining applications areas (breeding, synfuel research, etc.) or addressing reactor or engineering needs for a direct-drive system. Should we increase our activity in these areas? If so, what level of effort do you recommend?

For the current objectives of the program, significant involvement in applications seems unwarranted, given the limited resource base of the Laboratory. However, a certain amount of this activity is required to keep both LLE scientists and our sponsors aware of the long term strategies and potential applications of fusion. Do you believe our present support base could be enhanced by additional efforts in applications, particularly efforts involving joint research with public utilities or engineering firms?

Response: The Laser Fusion Feasibility Project (LFFP) at the LLE has as its primary mission and expertise the development of the body of science necessary to make Laser Fusion a practical reality. Therefore, it is incumbent on the staff of the LFFP to be aware of, and possibly participate in, any laser fusion reactor design exercises which are being or have been undertaken. Such activities will provide guidance to the scientific studies being carried out by the LFFP.

However, the Board does not feel it would be in the best interest of the Laboratory to undertake detailed application studies on its own. The Laboratory has neither the mission nor the resources to do so. If a potential sponsor indicates they wish to participate in the Project by concentrating on the application of Laser Fusion, the Board recommends the Laboratory insist the sponsor also make a substantial contribution to the science program of the LFFP. Otherwise, the sponsor could be a significant drain on the resources of the Laboratory.

The Board does feel, however, that it would be worthwhile for the LLE staff to pursue the potential application of the result of some of the non-fusion research. However, care must be taken to insure that these activities do not detract significantly from the scientific programs of the Laboratory.

HKF:pt0821F

STATEMENT FOR THE RECORD

SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

OF THE

SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

by the

LABORATORY FOR LASER ENERGETICS

UNIVERSITY OF ROCHESTER
Rochester, New York

Inertial Confinement Fusion Program at the University of Rochester

The University of Rochester's Program in inertial fusion is comprised of three distinct and complementary components: the DOE research program in direct-drive, operation of the facility for users (through National Lasers Users Facility (NLUF)), and the Laser Fusion Feasibility Project. More than $108,000,000 have been invested in the research programs, of which 48% has been derived from non-federal sources. Over $37,000,000 have been invested in building and laboratory equipment. Our current annual operating budget is about $9,000,000 of which salaries and their related benefits account for 60% of the total operating costs. The Laboratory for Laser Energetics (LLE) at the University of Rochester is both a cost effective and highly productive research center.

The purpose of the Rochester program is to support and enhance the DOE Military Applications program by providing laser-matter interaction data, capsule physics, and laser and optical engineering. During FY83, LLE made extraordinary progress in demonstrating the advantages of short-wavelength lasers for efficient coupling to fusion targets. Experiments at LLE with both the 24-beam, infrared (1054-nm) OMEGA facility and the single-beam, ultraviolet (351-nm) Glass Development Laser (GDL) have concentrated on the basic physics of coronal coupling, energy transport, and uniformity for short-wavelength, direct-drive laser fusion. This has been especially beneficial for providing some of the critical data, not otherwise available, needed to meet the milestones of the National Inertial Fusion Program.

Rochester was first to demonstrate and patent the high-efficiency, frequency-tripling process. This is now used in virtually every short-wavelength inertial fusion laboratory and has made glass lasers a potent research tool to achieve success in inertial fusion. A major highlight of the FY83 program was the completion of the conversion of the first six, ultraviolet (351-nm) beams of the OMEGA system. The initial six-beam conversion and experiments were completed on-time and on-budget and exceeded all the performance criteria established by DOE, according to the DOE report. In addition to the conversion activities, the GDL and OMEGA facilities provided 1,724 and 1,182 shots, respectively, for experiments during the year; 368 target shots were conducted for users of the NLUF.

In addition to its research mission which supports the DOE weapons program, the Laboratory continues to maintain a leading role in training students; over 21 Ph.D. thesis projects are in progress now. Previously, 37 students have completed their Ph.D. research at the Laboratory.

In FY 1984 an additional six OMEGA beam lines will be converted to 351-nm operation, leaving twelve more to be converted, which we hope to do in 1985. Little additional value can accrue to the National Program unless all 24 beams are converted. In order to carry out this activity, the Rochester Program requires a total operations budget of $7.5 million of which $1.4 million will be used for the ultraviolet conversion of 12 beams and $0.6 million for the National Lasers Users Facility plus $0.3 million for capital equipment. These funds are essential to fulfill LLE's scientific program. When this conversion activity is completed, we expect to perform significant, spherically symmetrical, ablative, target-implosion experiments which will help to define the conditions necessary for establishing the scientific feasibility of inertial confinement fusion. The data from these future experiments are critical to the National Program decision planned for 1987.

The demonstrated high-repetition rate and system reliability of OMEGA gives us confidence that the LLE facility will continue to be a valuable and unique resource, both for the National Inertial Fusion Program and for other users of the system.

FUSION POWER ASSOCIATES

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APRIL 1984

STATEMENT ON INERTIAL CONFINEMENT FUSION
DR. STEPHEN O. DEAN
PRESIDENT, FUSION POWER ASSOCIATES
PREPARED FOR
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
OF THE
SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

Thank you for the opportunity to present a statement on inertial confinement fusion.

I am deeply concerned with the Department of Energy's FY 1985 budget request for inertial confinement fusion. For several years now the Department has systematically reduced their requests for operating funds in this program relative to prior years. Only the foresight and vision of the Congress, which has regularly added money to the DOE request, has kept us from losing considerable numbers of talented scientists from this very productive program.

The people working in this program have constructed and operated laser and particle beam facilities at power and energy levels which seemed impossible 15 years ago. They have extended our understanding of nature of the interactions of intense laser and particle beams with matter. In the process important additional benefits have been spawned, including the new field of laser isotope separation, studies of weapons-related phenomena and direct energy beam weapons technology.

In light of the outstanding record of accomplishments established by workers in this field, it is incredible to me to witness the short-sighted budget cutbacks imposed on this program within a DOE defense budget which is expanding enormously.

I urge the Congress to continue to provide the support necessary to maintain momentum, progress and enthusiasm within the inertial confinement fusion program.

I also urge the committee to maintain an interest in the civilian applications of inertial fusion, which I believe remains promising. The Board of Directors of Fusion Power Associates has issued the following statement of views on the subject:

> "Inertial Confinement Fusion - Energy Applications
>
> There have been considerable pressures exerted on ICF program managers to downplay studies aimed at energy applications of inertial fusion. Fusion Power Associates believes that to respond to these pressures by reducing the minimal ongoing studies of potential energy applications of ICF is not in the national interest. Military research and development has historically led to many important contributions to the civilian sector and to the economy. Government sponsors should be proud of, and encourage, these connections. Permitting a reasonable percentage of the ICF funding to continue to be spent on energy applications is the best way to ensure that the nation ultimately derives full benefit from the ICF program."

"TO TAKE FROM THE SEA AND TO IMITATE THE SUN"

DEPARTMENT OF ENERGY RESEARCH AND DEVELOPMENT PROGRAMS—FISCAL YEAR 1985

TUESDAY, APRIL 24, 1984

U.S. SENATE,
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The subcommittee met, pursuant to notice, at 9:30 a.m., in room SD-366, Dirksen Office Building, Hon. Daniel J. Evans, presiding.

Present: Senators Evans and Levin.

Also present: Paul Gilman, professional staff member; Benjamin S. Cooper, professional staff member for the minority; and James T. Bruce, counsel for the minority.

OPENING STATEMENT OF HON. DANIEL J. EVANS, A U.S. SENATOR FROM THE STATE OF WASHINGTON

Senator EVANS. This hearing before the Subcommittee on Energy Research and Development of the Committee on Energy and Natural Resources will come to order.

Today we have the fiscal 1985 oversight hearings on the Department of Energy research and development programs, especially emphasizing today conservation and renewable energy.

I am delighted first to have with us the Honorable Pat Collins, Under Secretary of the Department of Energy, and we are ready for your testimony, Mr. Collins, and then we will have a single panel of the other public witnesses who will come up afterwards.

Mr. COLLINS. Thank you very much, Mr. Evans. If I may, I would like to have the entirety of the testimony included in the record and just provide a summary.

Senator EVANS. It will be included.

STATEMENT OF HON. PAT COLLINS, UNDER SECRETARY, DEPARTMENT OF ENERGY, ACCOMPANIED BY DONNA FITZPATRICK, PRINCIPAL DEPUTY ASSISTANT SECRETARY FOR CONSERVATION AND RENEWABLE ENERGY; ROBERT SAN MARTIN, DEPUTY ASSISTANT SECRETARY FOR RENEWABLE ENERGY; AND AL STREB, DEPUTY ASSISTANT SECRETARY FOR CONSERVATION

Mr. COLLINS. I also would like to introduce my colleagues here—Donna Fitzpatrick, Principal Deputy Assistant Secretary for Conservation and Renewable Energy; Bob San Martin, Deputy Assistant Secretary for Renewable Energy; and Al Streb, the Deputy Assistant Secretary for Conservation.

We certainly appreciate the opportunity to appear before you here today and provide some information on our Department's 1985 budget request.

As you know, Mr. Chairman, when I assumed the position, the Secretary of Energy gave me a special mandate in the area of conservation and renewable energy, and I am pleased to have focused on that the last 7 months.

One of my first initiatives was to establish a thorough review of the ongoing and proposed programs to ensure that adequate funding was available and adequate coverage was provided to a very broad spectrum of technological options.

The budget for these programs we think is very consistent with the fourth national energy policy plan announced in October by the President and the Secretary at the White House. It is also a great deal closer to what Congress has proposed in the past and consistent with the interests of the vast majority of the members of this committee, and at levels very similar to what they have appropriated in the recent past.

The overall goal of our national energy policy plan is an adequate supply of energy at reasonable prices, adequate supply being indicated as flexibility in this case with no undue reliance on any single source of supply.

The goal of reasonable cost suggests economic efficiency within that system. Our strategy is to minimize Federal control while maintaining public health, safety, and environmental quality, and promoting a balanced and mixed energy resource system.

The fiscal year 1985 budget request implements these strategies by supporting a mix of technology that contributes to energy supply and end use efficiency. In allocating our resources, we concentrate on applying Federal funds only where they are most effective. That is, we sponsor R&D where potential payoff is high but where private industry cannot be expected to invest because a return on investment requires an exceptionally long time to be realized, or because results are difficult to predict.

Efforts by the Department will also focus on improved dissemination of results of R&D programs and expanded collaboration with the private sector. We intend to improve upon our technology information program in order to better provide timely knowledge to the interested parties. A very important role certainly goes to the national laboratories. Laboratories are currently handicapped by a lack of specialized up-to-date equipment, and we address that in this budget as well.

Our proposed budget reflects a commitment to support a mix of technologies. With a stabilized conservation and renewable energy organization, we have taken the steps necessary to meet mandatory staff floors.

Before summarizing for you on budget requests for fiscal year 1985, I would like to give a brief overview of the Department's perspective in the field of energy conservation.

Energy conservation, energy efficiency, energy productivity, whatever term you use, certainly means the elimination of waste and the careful and efficient use of our resources. That is basic to our strategy. Our R&D technology transfer program will enable individuals and businesses to take cost-effective actions to reduce energy consumption, thereby reducing the need for new supplies. Therefore, we view conservation as a resource which must be managed like any other resource.

We also seek to promote a permanent conservation mentality throughout this country, so our focus is on increased economic efficiency and investing our energy dollars to achieve the greatest possible return. This, of course, will require investing in and development of new energy efficient technologies which can result in constant long-term reduction in energy consumption.

It is also crucial that Government officials emphasize the importance of conservation as Secretary Hodel and I have done on many occasions. We stress that consumers need to base their conservation efforts on both the current price and expected future price of energy. The effect of such a policy can be demonstrated by the recent past. Between 1973 to 1982, in real inflation-adjusted terms, the average price of petroleum roughly tripled. The price of natural gas rose similarly, and the average price of electricity increased by more than 50 percent. Largely as a result of these price increases, energy use per constant dollar GNP declined steadily. From 1972 to 1982, the Nation's energy efficiency improved 20 percent. This, of course, has been in response to higher energy prices and market forces.

Reliance on the market is a mainstay of our conservation policy, with DOE concentrating Federal funds on carefully targeted technological research and development, technology transfer, and direct energy improvement assistance for those who are least able to respond to the change in the energy market.

I would like to briefly summarize our budget requests for each of the major program areas. I think these proposals will reflect a very tangible commitment by DOE to conducting those activities which are necessary to sustain the technical momentum established in the Federal research community and industry.

In energy conservation R&D, our figure is $181.5 million. The Department's energy conservation R&D programs are designed to assist in the development of more efficient technologies and also alternative fuels, to those based exclusively on fossils.

In order to carry out these efforts, we are requesting funding of $35.3 million in buildings and community systems, $33.3 million in industrial program activities, $51 million for transportation, and $51.8 million for energy systems research. That latter category includes $26.5 million for the multisector programs and $18.2 million for electric energy systems, as well as $17.1 million for energy storage technologies.

The fiscal year 1985 budget request for renewable energy under this subcommittee's jurisdiction is $191.2 million. This represents an increase of approximately 90 percent over the fiscal year 1984 request by this administration in order to conduct the activities which are necessary to sustain this technichal momentum. In technical we are requesting $11.9 million in solar building energy systems, $47.5 million for photovoltaics, $37.5 million for solar thermal, and the funding request for the biofuels energy system is $28.1 million.

The request for wind and ocean energy systems programs are $23.3 and $3.5 million respectively.

In order to support a strengthened solar technology transfer effort, the Department is requesting fiscal 1985 funding of $6 million. In addition, we are requesting half a million dollars for international solar energy programs to assist U.S. industry in conveying the technical quality of their products to potential foreign users; $27.1 million is requested for geothermal, as well as $0.1 million for the geothermal resource development fund, and an additional half million is requested for small-scale hydropower efforts.

Certainly time will not allow me to go into the details, but I would like to mention a few highlights of our planned 1985 activities in both areas.

In the building and community systems program, research will be conducted not only into how to make building shells more energy efficient, but also how to maintain acceptable indoor air quality—a concern of many Members of Congress and the public as well.

The Department is also requesting funding to establish a Fellowship Program to support building energy studies by universities and industry researchers. At our DOE national laboratories a special effort is going to be made to encourage the participation of students and faculty members from historically black colleges and universities as well as State and local government employees.

Another of the research efforts will involve development of improved burner designs and sophisticated combustion controls for industrial applications. In transportation, we will be conducting research of gas turbine and adiabatic diesel technologies with the goal of 30 to 40 percent improvement in our energy efficiency over existing technologies.

In energy conversion and utilization technologies, which I think is one of the most exciting programs, we will conduct research and development of materials which have great potential for improving the efficiency and performance of high temperature processes.

In energy storage technologies, one area of activity will include exploratory development of sodium zinc-bromine batteries. The sodium-sulfur battery appears capable of providing at least five times the energy storage capability per unit as previous batteries that we have done research on.

Recent articles in the popular press, of course, tie certain forms of cancer to magnetic field exposure, which can result from the use of high voltage direct current transmission. Public concern is growing, and research will be initiated to assess the validity of this concern.

The superconducting transmission cable project will examine new insulating materials for use at ambient temperature and the feasibility of the transfer of bulk power by high voltage direct current transmission. Five million dollars has also been requested for an energy-related inventions program to support development of an anticipated 50 to 75 energy-related private sector inventions generally from small business people, and I think this is one of our very exciting programs.

I think in the renewable area, photovoltaics is continuing to show progress, and we will be looking into multilayered cells which offer potential conversion efficiencies up to 35 percent.

Additionally, the Department is proposing to upgrade the capabilities of the Device and Measurement Laboratory at the Solar Energy Research Institute, a world-leading research center which evaluates 500 to 1,000 photovoltaic cell materials each year.

The Solar Thermal program will investigate the concept of allowing the operation of solar thermal equipment in temperatures in excess of 1,500 degrees.

The biofuels area will include a new genetics program to develop wood resources with high yields, improved resistance to pests and disease, lower nitrogen or water requirements. In addition, research will be conducted to improve the oil content, increase growth rates, and to determine methods for harvesting microalgae as an energy resource.

Other research efforts will include the development of materials that can withstand the severe ocean environment and identification of reservoirs suitable for the extraction of energy from molten rock.

Let me conclude, Mr. Chairman, by saying that we are extremely delighted about this budget and the mixed and balanced approach as announced in NEPP-IV. The private and public cooperation, with State and local government, in effective technology transfer efforts will enhance this Nation's ability to use the results of our R&D efforts.

The programs presented for your review today represent a stable commitment to the continuing development of these technologies. We are confident, Mr. Chairman, that these proposals will increase understanding of the potential for virtually all of the most promising conservation and renewable technologies, and substantially contribute to the base of technical information required by those in decisionmaking positions.

We are extremely pleased with the cooperation of the members of this committee and their staffs and the staff of this committee in preparing this budget, and we look forward to working with you in the future.

Thank you very much, Senator Evans.

[The prepared statement of Mr. Collins follows:]

STATEMENT OF HON. PAT COLLINS, UNDER SECRETARY, DEPARTMENT OF ENERGY

Mr. Chairman and Members of the Subcommittee, I appreciate this opportunity to appear before you today and provide information on the FY 1985 budget request concerning the Department's Conservation and Renewable Energy programs. The budget for these programs was developed in concert with the Fourth National Energy Policy Plan (NEPP-IV), published in October 1983, and fully supports the goals and strategies set forth in that document. I will summarize those parts of the Plan which are relevant to the subject of today's hearing and discuss related highlights of the FY 1985 budget request.

NATIONAL ENERGY POLICIES AND STRATEGIES

The goal of national energy policy is to foster an adequate supply of energy at reasonable costs. An adequate supply requires a flexible energy system that avoids undue dependence on any single source of supply, foreign or domestic, and thereby contributes to our national security and economic stability. The strategies for achieving this goal include:

- Minimizing federal control and involvement in energy markets while maintaining public health, safety and environmental quality, and
- Promoting a balanced and mixed energy resource system.

CONSERVATION

The FY 1985 budget request implements these strategies by supporting development of a mix of technologies that can contribute to both energy supply and improved end-use efficiency. Energy conservation, which we define as the elimination of waste and the careful and efficient use of resources, is a basic component of these strategies. We view it as an important energy resource. Indeed, the experience of the last 10 years has proven this to be the case. Between 1972 and 1982 the Nation's energy efficiency improved 20 percent. The resulting energy savings are equivalent to about 8 million barrels of oil per day--considerably more than that which we now import. While energy conservation is motivated by energy prices and market forces, the Department of Energy plays an important and facilitating role. Our objective is increased productivity. This will require the development of new energy efficient technologies which will result in a constant, long term reductions in energy consumption. Federal funds are being concentrated where they are most effective, that is, in sponsoring research and development (R&D) in the areas where the potential payoff is high but which private industry cannot be expected to pursue alone.

RENEWABLE ENERGY

Renewable energy resources can play an important role in reaching a balanced and mixed energy supply system. Renewables offer supply diversity, modularity of system sizes, and flexibility in meeting a variety of end use demand. Collectively, their modularity and flexibility in direct thermal applications, bulk electricity supply, or in meeting requirements for liquid and gaseous fuels, makes them highly attractive alternatives for private sector development and deployment. As technological advances improve renewable technology viability, there will be increased diversity within the nation's future energy supply infrastructure and an increase in competition within the energy marketplace. The federal strategy for renewable energy R&D is to concentrate on scientific and engineering research which will lead to a better understanding of: the characteristics of renewable energy resources; the mechanisms for converting these resources to more useful energy forms; and the materials to ensure that the systems can achieve the necessary reliability and efficiency.

An example of the progress made to date can be seen in photovoltaics. Multi-layered cell research has advanced from its initial conceptualization in 1980, to achievement of recently attained 22 percent experimental efficiency. Equally important is the fact that research at the Solar Energy Research Institute (SERI) and at industrial laboratories has significantly increased understanding of the basic photovoltaic effect. Today, scientists and engineers openly debate the most suitable concepts to reach conversion efficiencies of 35 percent, a figure not considered realistic three years ago.

The program presented for your review today represents a sound and stable commitment to the continuing development of these technologies. We are confident that these proposals will increase understanding of the potential for virtually all of the most promising options within renewable energy and will substantially contribute to the base of technical information required for informed decision making regarding renewable energy.

Especially important is the Department's proposal to increase its emphasis on technology transfer activities. Through these activities the Department intends to gain additional insights into industrial research priorities early in the federal planning process and improve upon an already effective technical information program in order to better provide timely knowledge to interested parties in a form responsive to their specific needs.

FY 1985 BUDGET REQUEST FOR ENERGY CONSERVATION

The Administration's FY 1985 budget request for energy conservation R&D and mandated programs totals $181.5 million. The Administration's total request of is considerably more than the $98.0 million requested for these programs last year. This increase underscores the Administration's renewed commitment to energy conservation.

The $181.0 million requested in the DOE budget for energy conservation R&D will be used to continue ongoing R&D efforts and to initiate several new activities including: new and expanded R&D efforts; increased emphasis on technology transfer; a fellowship program which will sponsor private researchers at the Department's national laboratories; and increased investment in capital equipment. The request also includes funds to carry out the conservation related activities and programs mandated by Congress including: the Residential Conservation Service and the Commercial and Apartment Conservation Service; the Appliance Standards Program; the Building Energy Conservation Standards and Guidelines Program (formerly the Building Energy Performance Standards); the Federal Energy Management Program; the Industrial Reporting Program; and preparation and publication of the Gas Mileage Guides.

I would like now to address the funding requests for selected major programs.

BUILDINGS AND COMMUNITY SYSTEMS

The FY 1985 budget request for the Buildings and Community System program is $35.3 million. These funds will be used to conduct three major activities: (a) research and development into advanced technologies that will increase the energy efficiency of buildings; (b) information and technology transfer activities that will make the results of our R&D available to potential users, and (c) implementation of the building energy regulatory programs mandated by the Congress. These activities will encourage improved efficiency in the use of energy in the buildings sector, which accounts for approximately 36 percent of total national energy consumption.

Research and development activities consist of three subprograms: Building Systems, Technology and Consumer Products, and Community Systems. The objecttive of the Building Systems subprogram is to develop a technological base that will enable the private sector to construct more energy efficient buildings and to upgrade the energy efficiency of existing buildings. In FY 1985 $12.2 million is requested for this subprogram, with the funds supporting: research on building shells; ways to maintain acceptable air quality in energy efficient buildings; methods to predict and measure the energy performance of buildings; means to retrofit existing buildings to make them more energy efficient; energy efficiency measures and their interactions; and development of home energy rating systems. A portion of these funds will also support a restructured building energy performance standards effort--a Congressionally mandated regulatory program, which I will discuss separately.

The Technology and Consumer Products subprogram supports research that will increase the efficiency of energy related equipment used in buildings. The objective of this subprogram is to provide a technological base that will enable industry to develop and commercialize energy efficient equipment technologies. In FY 1985 $4.9 million is requested for this subprogram. These funds will be used for research into advanced technologies which support development of more efficient, thermally activated heat pumps and advanced energy efficient lighting concepts--technologies which promise a 30 percent increase in efficiency over existing equipment.

The Community Systems subprogram supports research leading to the development of community-wide energy delivery and management systems. An example of this technology is district heating. In FY 1985 $2.0 million is requested for this subprogram to be applied to the development of integrated community energy systems.

Information and technology transfer activities for the Building and Community Systems program are carried out under the Analysis and Technology Transfer subprogram. In FY 1985 $4.5 million is requested for this sub-program. These funds will support continuation of cooperative efforts with the International Energy Agency and will also be used to undertake two new technology transfer initiatives. The first initiative will establish an Energy Efficient Buildings Center, which will display new materials, technologies and equipment, and serve as a clearing-house for R&D results as well as innovative technologies. The second initiative will establish a fellowship program that will support building energy studies by private sector researchers at the DOE national laboratories. Students and faculty members from historically black colleges and universities and state and local government employees will be specifically targeted for participation.

Finally, $2.5 million is requested for capital equipment in support of the Buildings and Community Systems program in FY 1985. These funds will be used for roof testing equipment at the Oak Ridge National Laboratory, for model building simulation equipment at a university or research laboratory to be selected later, and to replace outmoded test equipment at a number of DOE national laboratories.

INDUSTRY

The FY 1985 budget request for the Industrial programs is $33.3 million. These funds will be used to carry out work in four subprograms: Waste Energy Reduction, Industrial Process Efficiency, Industrial Cogeneration, and Implementation and Deployment. The goal of these activities is to encourage improved energy efficiency in industry, which accounts for approximately 37 percent of total U.S. energy consumption. The Department's activities in the industrial area consist of a comprehensive program of carefully targeted technological research and development, combined with technology transfer and other implementation efforts. The R&D activities focus on high risk ventures and most are carried out by private institutions operating under cost-shared or cooperative agreements with the Department.

The Waste Energy Reduction subprogram supports research and development on improved combustion efficiency through: oxygen enrichment, improved burner designs, and sophisticated combustion controls; development of industrial heat pumps, high temperature recuperators, and ceramic materials for heat exchangers; and research into waste materials utilization and CO_2 recovery and utilization. In FY 1985 $12.4 million is requested for this subprogram.

The Industrial Process Efficiency subprogram includes R&D for thin strip casting of steel, inert anode materials, advanced heat processing sensors and control systems, membrane separation systems, and gasification of wood derived process liquids for use as fuel. In FY 1985 $8.0 million is requested for this subprogram. This R&D effort is aimed at capturing as much as 1.0 quadrillion BTU of potential energy savings per year. The Cogeneration subprogram supports research into coal-fired Brayton cogeneration systems, cogeneration systems powered by diesel engines fired by coal and water slurries, and thermionic burner systems. In FY 1985 $3.2 million is requested in this area.

In addition to the R&D activities which will be funded by the FY 1985 request, there are a number of other R&D activities which are ongoing and supported by prior year funding. These projects include fluidized-bed waste heat recovery systems, utilization of waste materials, sensors and control systems, separation systems, and cogeneration component research, all of which have significant energy conservation potential.

The Implementation and Deployment subprogram continues support for the Energy Analysis and Diagnostic Centers at 10 universities, carries out the Congressionally mandated Industrial Energy Efficiency Reporting program and supports a number of new initiatives in technology transfer. These new initiatives include fellowships for private sector researchers at the national laboratories, and the establishment of a national information center for industrial energy conservation technology and R&D results. Altogether, $3.5 million is requested for this subprogram. Finally, the FY 1985 budget contains $4.4 million for new equipment and instrumentation to enhance research activities at the DOE national laboratories.

TRANSPORTATION

The FY 1985 budget request for the Transportation program is $51.0 million to continue R&D activities in five subprograms: Vehicle Propulsion R&D; Electric and Hybrid Vehicle R&D; Transportation Systems Utilization; Alternative Fuels Utilization; and Advanced Materials Development. These activities focus on the transportation sector, which consumes 9 million barrels of oil per day and accounts for approximately 27 percent of total national energy consumption and about 60 percent of total use of petroleum. The goal of the Transportation program is to provide the technology base necessary to support private sector efforts to improve energy efficiency in transportation and to develop new technologies which can serve as alternatives to those based exclusively on petroleum.

In FY 1985 $18.5 million is requested for the Vehicle Propulsion subprogram which supports research and development of high efficiency and advanced heat engine technologies. This area includes R&D on the automotive gas turbine and the adiabatic diesel, and carries out a number of technology transfer and technology assessment activities. The goals for both the gas turbine and the adiabatic diesel projects are to develop proof of concept engine designs which result in 30 to 40 percent improvement in energy efficiency over existing technologies, meet current standards for emissions, safety, and noise; as well as having the capability to use several different alternative fuels.

In FY 1985 $6.8 million is requested for the Electric and Hybrid Vehicle subprogram, which supports R&D activities necessary to advance the technologies of electric batteries and electric propulsion systems. These funds will be used to continue the development of experimental aqueous (lead-acid and nickel-iron) battery systems, flow (zinc-bromide) battery systems, and a number of integrated propulsion systems, including advanced powertrains.

The Transportation Systems Utilization subprogram is designed to encourage improved energy efficiency in transporation systems use. The FY 1985 budget requests $1.7 million to support publishing of the Gas Mileage Guide, conduct training in energy efficient driving techniques, and encourage ride sharing activities.

In FY 1985 $1.5 million is requested for the Alternative Fuels Utilization subprogram, which is designed to encourage the use of non-petroleum based fuels in transportation. These funds will be used to conduct systematic investigations into the fundamental behavior of alternative fuels in both spark ignition and diesel engines, and to develop and maintain data bases on the physical, chemical, and combustion properties of alcohol and other fuels derived from oil shale, coal, and biomass.

In FY 1985 $17.6 million is requested for the Advanced Materials Development subprogram. This area addresses the need to develop advanced materials and engine components that can withstand the high temperature and corrosive environments of high performance energy conversion systems for automotive applications. Of these funds, $7.0 million will be used to develop a technological base in ceramic and ceramic composites. This will be accomplished through research into the fundamental areas of ceramic materials processing, design methodology, materials characteristics and performance under stress, and useful life prediction. The remaining $10.6 million will be used to complete construction of the High Temperature Materials Laboratory at Oak Ridge, Tennessee. Finally, $3.0 million is requested for capital equipment in support of both the Advanced Materials Development and the Electric and Hybrid Vehicle subprograms.

ENERGY SYSTEMS RESEARCH

ENERGY STORAGE

The Energy Storage Technologies (EST) program serves as the nucleus for virtually all research activities related to energy storage within the Department of Energy. The program conducts research on energy storage technologies to support the private sector development of efficient, reliable, economic, safe, and environmentally acceptable energy storage systems. The FY 1985 budget request for the Energy Storage program is $17.1 million.

The $14.9 million Battery Storage activity consists of technology base research and exploratory technology development and testing. The technology base research activities encompass fundamental research with the overall objective of providing the basis for improvements in existing battery systems and the identification and development of new battery and fuel cell systems. Objectives of the exploratory technology development and testing activity include development and evaluation of high-performance, long-life, economical, and producible batteries for future mobile and stationary energy storage applications.

Two aims of the technology base research are to improve materials and components of cells and batteries and to understand selected electrochemical phenomena, including corrosion. Experience has shown that materials limitations within electrochemical systems are the principle cause for failing to meet established system-performance goals. Improved materials and components will lead to improved energy efficiency, lower capital cost, and increased cycle life, energy, and power density of electrochemical devices.

In FY 1985, the exploratory technology development and testing activities will concentrate on sodium-sulfur and zinc-bromine batteries, as well as battery testing and post-test analysis of other types of batteries. The sodium-sulfur battery has the potential for the highest performance of any of the battery systems currently in the exploratory development phase. This battery appears capable of providing five times the energy storage capability per unit of present commercial lead-acid batteries. In addition, this battery appears capable of higher efficiency of operation. Program activities will emphasize continued development of cells with improved life and reliability.

The $1.3 million Thermal and Mechanical Energy Storage activity includes two major types of sub-activities: thermal energy storage and chemical (hydrogen) storage. The aims of the project are to develop low cost thermal chemical heat storage components. In the thermal storage area, activities will emphasize thermal/clathrate systems as well as form-stable phase change materials. Chemical/hydrogen activities will focus on developing efficient, cost competitive processes for producing hydrogen from water (high and medium temperature electrolysis) and providing the technology for safe and cost-effective storage, transmission, and distribution of hydrogen.

ELECTRIC ENERGY SYSTEM

The Electric Energy Systems program supports research aimed at: (1) determining the biological health effects and risks to humans exposed to high-voltage electric fields; (2) providing options that will enhance reliability of the nation's electric networks under all normal and emergency situations; and (3) improving the efficiency of electric systems through new materials, advanced controls, and new design concepts. The FY 1985 request for Electric Energy Systems is $18.2 million.

The Electric Fields Effects Research request is $3.7 million to provide biological data on electric field exposure and determine methods for extrapolating data from tissue and cell studies and from laboratory animal experiments to human effects. Efforts will be increased to determine the mechanisms by which electric fields interact with biological materials and provide a method for human effects analysis. The use of high voltage direct current (dc) transmission is rapidly growing in the U.S., but a major unknown is the impact of dc ions on living organisms. Recent articles in the popular press tie certain forms of cancer to magnetic field exposure. Public concern is growing and research will be initiated to assess the validity of this concern.

The $4.5 million Reliability Research activity will be expanded in FY 1985 in order to: (1) assess the impact of a nuclear electomagnetic pulse (EMP) on the Nation's electric network; (2) develop computer-aided technologies to enhance the reliability of electric power systems during normal and abnormal operation; (3) continue to develop more effective operating strategies for electric systems under stress, with computer-aided methods for problem recognition, analysis, and corrective action alternatives.

A total of $9.3 million has been proposed for Systems Technology to increase the efficiency and effectiveness of the nation's electric utility networks. The superconducting transmission cable project will examine new insulating materials for use at ambient temperatures. High voltage direct current (HVDC) transmission may be an alternative to alternating current lines for the transfer of bulk power. Research will be increased on this method of power transmission. Increased activity is also being proposed in the exploratory development of materials for future components and systems. These will include electrical insulating materials, magnetic conducting materials, and power semiconductor materials. This research will concentrate on understanding the basic molecular structure and will attempt to tailor materials more nearly to their use. The objectives of this research are improved efficiency (reduced losses), higher reliability, lower cost, and providing the technology base required to enhance productivity and to maintain technologial leadership.

MULTISECTOR

The Multisector Program includes the Energy Conversion and Utilization Technologies (ECUT) program, the Energy Related Inventions program, and the National Appropriate Technology Assistance Service. The FY 1985 budget request for Multisector includes $21.5 million for ECUT and also includes $5.0 million for the Energy Related Inventions program.

The Energy Conversion and Utilization Technologies research programs are oriented toward basic research and crosscutting R&D problems common to more than one energy consuming sector. They also provide predictive models and design tools useful to the private sector in achieving greater energy productivity. The requested funding will be used to conduct research in four subprogram areas: Combustion and Thermal Sciences, Materials Sciences, Biocatalysis, and Tribology.

In FY 1985 $5.8 million is requested for Combustion and Thermal Sciences Subprogram. Combustion research provides analytical and measuring techniques needed to understand the thermochemical and related processes that take place in the combustion of fuels and in the conversion of the released thermal energy to work. The results of this research are used to develop efficient, clean, and reliable combustion systems and devices. Thermal Sciences research develops improved thermodynamic analytical capabilities and experimentally validated computerized data bases. These are needed to provide the technological base used to improve heat transfer coefficients, reduce heat transfer surface area requirements, and minimize vibration induced by fluid flow through heat exchangers. In FY 1985, a study of fluidized-bed heat transfer phenomena will be completed. Research will continue to develop advanced analysis techniques and to generate a technological data base for the physical sciences of thermodynamics and heat and mass transfer.

The $6.0 million requested for Materials Sciences research will be used to investigate high-temperature materials, lightweight materials, and corrosion resistant materials. Certain materials such as Long-Range Ordered (LRO) Alloys and Intermetallic Compounds, both of which have highly ordered atomic structures, have great potential for improving the efficiency and performance of high temperature processes, but have not yet been utilized because of their characteristic brittleness. Also, research on high-temperature materials in other areas will be expanded in FY 1985. The $2.0 million requested for Biocatalysis research will be used to establish a technological data base for the development of new techniques to manufacture industrial and commercial chemicals using biological systems analogous to conventional processes in chemical engineering. The $3.0 million requested for the Tribology subprogram will be used for research on lubricants, friction and wear of ceramics, coatings on machine tools that reduce heat and last longer, and refinement and quantification of friction energy losses in the U.S. economy.

Other ECUT funding requested in the proposed FY 1985 budget will: provide seed money for innovative or revolutionary concepts for alternative fuel use and improved energy efficiency in energy conversion, storage, and end-use; be used for program direction; provide capital equipment to replace currently outmoded equipment at DOE national laboratories; and support a number of technologytransfer initiatives.

The FY 1985 budget requests $5.0 million for the Energy Related Inventions program. This program was established to evaluate the technical merits of energy related inventions submitted to DOE and to provide technical assistance and grants to further develop promising inventions. NBS conducts evaluations through its Office of Energy Related Inventions. Promising inventions identified by NBS are directed to DOE for further assistance to investigate sources of private sector funding or for direct support where private sector support is not available. By 1983 approximately 20,000 energy saving inventions had been evaluated by NBS. Based on NBS recommendations, 164 inventions were awarded grants totalling $12.8 million. Of these, 35 have entered the marketplace generating sales of $178 million and creating more than 700 direct jobs. In FY 1985 the funds for this subprogram will be used to evaluate approximately 2600 new proposals with an estimated 50 to 75 private sector inventions being approved for further development.

The Department is not requesting funding for the National Appropriate Tehnology Assistance Service in FY 1985 because the $2.0 million appropriated in FY 1983 and FY 1984 is sufficient to maintain continuity of this program through FY 1985.

FY 1985 BUDGET REQUEST FOR RENEWABLE ENERGY

The FY 1985 budget request for Renewable Energy is $191 million. For comparison purposes, last year's request was $102 million for these programs. (See attachment).

I would now like to address the funding requests for selected major programs.

SOLAR BUILDING ENERGY SYSTEMS

Solar building energy technologies employ direct and indirect solar radiation to provide heating, cooling, and natural lighting for buildings. The FY 1985 budget request for Solar Building Energy Systems is $11.9 million. These funds will be used to conduct R&D activities in support of industry development of low and medium temperature solar collector concepts and construction techniques that can result in reduced energy requirements for buildings.

The Department is requesting $7.2 million for Materials and Components Research to develop and test light-weight materials for use in low-cost, durable nonmetallic collectors. Research will also be undertaken on cost effective solar absorption and Rankine cooling technologies. Glazing materials that transmit solar energy, but resist heat losses, will also be studied. When used for windows, these materials have the potential to significantly reduce cooling loads, prevent overheating, and provide improved natural lighting to interior building spaces. Testing will be conducted on thermal storage materials that offer properties of low weight and durability, and are suitable for building materials or components.

In Heat Transfer Systems Analysis, the Department is requesting $3.2 million for research to better define performance of solar systems. One-of-a-kind components will be tested and evaluated to identify the most promising and effective design approaches. Within this area, passive solar techniques for non-residential structures will be examined to further understand natural heat distribution systems, to determine the impact of building space conditioning loads upon utility demands, and to assess the effectiveness of alternative cooling and lighting technologies. The capability to fully utilize available natural light will be assessed under various climate conditions in conjunction with new lighting techniques.

Finally, in Thermal Science Research, $1.3 million is requested to conduct research to identify and evaluate promising innovative concepts for solar heating and cooling. In particular, research will be conducted on cooling processes such as evaporation and ventilation to determine the limits of these concepts for effective cooling of buildings.

PHOTOVOLTAIC ENERGY SYSTEMS

Photovoltaic technology directly converts solar radiation to an electric current. The FY 1985 budget request is $47.5 million to continue the development of a technology base from which private enterprise can select and develop competitive applications for electrical energy markets.

The Department proposes $31.0 million for Materials Research to overcome the technical barriers currently limiting the efficiency and cost of photovoltaic cells. The work will focus on single-layer thin film cells, new high-efficiency techniques, silicon sheets and innovative concepts. For single-layer thin film cells, research will concentrate on increasing cell efficiency, with a goal of achieving 15 percent efficiency, as well as continuing to improve cell stability and lifetime. Photovoltaic cells made of thin film materials offer the potential for reducing material requirements and lowering production costs through the use of automated manufacturing processes.

Advanced high-efficiency techniques will focus on the development of multilayered photovoltaic cells. These cells offer the potential to achieve very high conversion efficiencies of up to 35 percent. Activities in this area will include the fabrication of multiple cells through the layering of different materials so that each layer converts a different portion of the solar light spectrum into electricity.

DOE proposes to fund research to address those remaining key issues which currently preclude full scale automated production of silicon. Automated silicon production technology may overcome the low yield and quality control problems inherent in state-of-the-art production technologies. Additionally, the Department is proposing to upgrade the capabilities of the Device and Measurement Laboratory at SERI, a world leading research center which evaluates 500 to 1000 photovoltaic cell materials per year.

The Department proposes to complement the previously described materials research activities with an innovative concepts and university research program that draws upon the creative genius of the nation's universities, private research laboratories, and small businesses. Funds will be provided for the best new ideas proposed by these organizations to conduct research to determine the R&D potential of new materials or innovative concepts for photovoltaic devices.

The Department requests $10.5 million for Collector Research to improve the efficiency and durability of both flat plate and concentrator modules. Flat plate collector research will result in increasing the efficiency of crystalline silicon cells through the development of improved coatings and low-cost electrical conductors. Concentrator collector research will be focused on the development of cells which can potentially achieve efficiencies of 20 to 23 percent in concentrated sunlight.

The Department requests $5.0 million in Systems Research to better define remaining photovoltaic reliability and life expectancy issues. A variety of PV modules will be tested under different operating and environmental conditions. Lessons learned, such as how to avoid electrochemical corrosion, improve voltage insulation, and prevent high voltage failure through improved circuit designs will be transferred to industry for further development and verification.

SOLAR THERMAL ENERGY SYSTEMS

Solar thermal technology employs concentrated sunlight to produce heat, electricity or both. The FY 1985 budget request for the Solar Thermal Energy Systems program totals $37.5 million. Innovative solar thermal concepts will be investigated to develop high performance, reliable solar energy systems that are cost competitive for electric and process heat applications.

The Department is requesting $8.9 million for Materials and Component Research. Experiments will be conducted to define the physical properties of potential heat transfer materials such as molten salts for solar thermal receivers and storage devices. Materials which may reduce the cost and weight of solar concentrators will be developed and evaluated. Finally, the materials used for receiver, delivery, and storage devices will be evaluated to determine their suitability for operating within a high temperature environment.

The request of $4.5 million for Concentrator Research and Development will be used to develop potentially low-cost, high performance concentrator concepts. Scale models will be tested and system analyses will be conducted to identify trade offs among collector performance, spacing, and cost of the various alternatives.

The $16.5 million requested for Central Receiver Research and Development will be used to examine concepts that show promise of attaining the substantial performance gains expected if solar thermal technology can be developed to operate at temperatures in excess of 1500°F. Advanced control concepts will be evaluated at the Central Receiver Test Facility and the power production phase of the Barstow 10 MWe Central Receiver Pilot Plant will be initiated.

In Distributed Receiver Research and Development, the Department requests $7.1 million to sponsor a one time cost-shared activity to design, build and evaluate first generation Stirling and Brayton engines. The results of this experiment should provide a sufficient technical basis for industry to determine the development potential of solar dish to electricity technology. A variety of other supporting research aimed at resolving critical distributed receiver engineering issues, including the operation of the Distributed Receiver Test Site, will also be undertaken in FY 1985.

BIOFUELS ENERGY SYSTEMS

Biofuels technologies are potentially capable of converting various feedstocks, such as forest wastes, animal wastes, and agricultural residues into liquid, gas, or solid fuels. The total biofuels request of $28.1 million will be evenly balanced between feedstock development and the continuing evaluation of promising conversion technologies.

The Department is requesting $4.2 million for Short Rotation Intensive Culture research. Research has shown that productive yields may be obtainable for certain species of woody biomass such as hybrid poplar and black cottonwood through the use of advanced agricultural methods. Especially important, the

Department plans to fund a new genetics program to develop wood resources with high yields, improved resistance to pests and disease, lower nitrogen or water requirements, and improved energy characteristics such as higher Btu content or lower moisture content.

The Feedstock Production request is $6.2 million. Research to better define the energy potential of crops that can be grown on grasslands or in water will be performed. As part of this research the Department will identify and improve herbaceous crops which have the potential of being grown on marginal lands. In addition, research will be conducted to improve oil content, increase growth rates, and to determine methods for harvesting microalgae as an energy resource.

The $7.0 million request for Thermochemical Conversion is for research to improve processes for converting biomass into liquid fuels and gas. Tests on various conversion concepts such as gasifiers and thermochemical reactors will be conducted to better understand their operation. Research and development will be conducted to improve the technology for using municipal waste as a fuel within acceptable environmental constraints. Research will also be conducted to evaluate various techniques for converting wood to liquid fuels.

The Department is requesting $6.6 million for Biochemical Conversion. Research will include investigations of biochemical reactions which can produce ethanol from various feedstocks. A major technical milestone will be accomplished when a 25 ton per day experiment begins operation as a technical baseline for acid hydrolysis of biomass. Improved methods for alcohol/water separation and for anaerobic digestion of feedstocks will be evaluated under laboratory conditions. The Refuse-Conversion-to-Methane (Refcom) facility at Pompano Beach will also be operated to evaluate methane production from a combination of sewage sludge and municipal solid waste.

The Department requests $3.1 million to fund the Regional Biomass Program which serves as a focal point for biofuels technology transfer activities. These regional programs will provide regional-specific information concerning biomass feedstock resources, feedstock conversion technologies and potential end-use applications to localities and industry in a form suited to their needs.

WIND ENERGY SYSTEMS

Wind energy involves the conversion of the energy of moving air into more useful forms, such as electricity. The Department requests $23.3 million to continue development of the technology base to support industry development of cost-effective and durable wind conversion technologies.

For the $8.8 million requested in Aerodynamics Research, an improved understanding of the essential interaction between wind turbine airfoils and the wind will be gained. The performance of wind machines under actual operating conditions and in different environments will be evaluated. Airfoil shapes and operating strategies which may improve the long-term performance of wind machines will also be analyzed and tests will be conducted at windfarms to determine how the location of multiple wind machines influences the performance of each individual machine.

DOE requests $7.7 million for Structural Dynamics research to improve the ability of industry to accurately predict structural loads. The structural performance of commercial and the DOE MOD-2 wind machines will be carefully monitored and evaluated to determine the natural resonant frequencies of modern wind machine designs. Samples of materials commonly used for wind machine blades, such as wood/epoxy, fiberglass, and aluminum, will be tested to determine the potential durability of these materials in different operating conditions.

The $1.7 million request for the Small Systems Test Center at Rocky Flats will provide testing and engineering support to industry. Analytical tools and design information developed through the Rocky Flats testing program will be provided to manufacturers, windfarm users, universities, and utilities.

The Department intends to complete its portion of the MOD-5B design and evaluation process under the FY 1985 request of $4.2 million.

OCEAN ENERGY SYSTEMS

Ocean energy technology involves the extraction of energy from ocean waves, currents, tides, and salt or thermal gradients. The FY 1985 budget request of $3.5 million will be focused on understanding ocean thermal energy conversion (OTEC) systems for generation of electrical power.

The $1.0 million request in Materials and Structures Research will center on the development of materials that can withstand the severe ocean environment Fiberglass reinforced plastic pipe will be tested to determine its fatigue parameters. Techniques for installation of safe and secure OTEC components in the rugged ocean environment will be developed and tested.

The $1.4 million for Thermodynamics Research and Analysis will support a variety of research to improve the understanding of thermal stress and fatigue, and improvements in OTEC heat exchangers to increase overall efficiency of this critical component.

In Experimental Verification and Testing, $0.6 million will fund the development and experimental verification of generic computer models at the Seacoast Test Facility.

The $0.5 million request for Environmental and Oceanographic Research will be used to study the impact of the extraordinary large water requirements for OTEC systems. Changes that may occur in the environment as related to the siting of OTEC systems will be evaluated within the DOE request.

INTERNATIONAL SOLAR ENERGY

The International Solar Energy Program serves to assist U.S. industry in conveying the technical quality of their products to potential foreign users. The FY 1985 budget request is $0.5 million.

The Department of Commerce will be funded to enter into cost-sharing agreements with industry to provide for international exposure of American solar technology at foreign expositions and other trade events. Additionally, domestic seminars will be conducted to enable U.S industry to better understand international trade opportunities and the best methods for offering U.S. technology abroad.

SOLAR TECHNOLOGY TRANSFER

DOE considers technology transfer a two-way process through which industrial priorities are considered early in the federal planning process and which provides a mechanism to transfer research results, experiences and "lessons learned" to groups and individuals within the private sector research and manufacturing communities. Thus, technology transfer is a vital link between the public and private sectors in the research and development process. The program request for FY 1985 is $6.0 million.

The Departmental request of $3.2 million for Solar Technical Information and Mandated Reports will provide for continuation of the SERI technical information program and the preparation of reports mandated by law.

The Department is requesting $2.2 million for the continued operation of the Conservation and Renewable Energy Inquiry and Referral Services (CAREIRS) which provides general information to the public concerning conservation and renewable energy technologies. CAREIRS also provides referrals to appropriate organizations or publications for persons who request detailed technical information.

The request of $0.4 million for Technology Transfer Assessments will be used to evaluate in cooperation with industry innovative technology transfer methods for improving information flow between the public and private sector. A variety of methods including seminars, workshops, conferences, cooperative research projects, cost-sharing, fee-paid user test facilities, and technology transfer centers will be reviewed and evaluated.

A series of Seminars and Workshops will be funded with the Departmental request of $0.2 million. These forums will ensure that an open and meaningful dialogue is maintained between the DOE and the private sector.

GEOTHERMAL

Geothermal energy involves the direct use of the natural heat of the earth and its conversion to other useable energy forms. The FY 1985 budget request of $27.1 million will allow continuing resolution of technical barriers to the use of geothermal resources.

The $3.5 million request for Geopressured Resource research will allow continued testing of Gulf Coast geopressured production wells to better quantify the potential of this resource. The Department also proposes to develop, install and evaluate a wellhead electric generator suited for operating at this type of geothermal well in cooperation with industry.

The $5.5 million request for Hot Dry Rock research at Fenton Hill will provide a basis for verifying the potential of this geothermal energy extraction technique. The feasibility of constructing a multiple-fracture, large scale reservoir with a project life of at least ten years will be specifically evaluated.

The Department requests $9.9 million for Hydrothermal research activities to address injection of unuseable geothermal waters, define reservoir characteristics, and conduct heat cycle research materials testing at the Geothermal Test Facility. Especially important, DOE will fund the drilling of a very deep hydrothermal well to examine the characteristics of deep hot water reservoirs to better define the potential of this form of geothermal energy. Mapping techniques will be field tested to locate natural fracture systems within hot water reservoirs to provide a better basis for defining this resource potential. The feasibility of tapping potential hydrothermal reservoirs associated with volcanic craters of the Cascade Range will also be evaluated under the Department's FY 1985 request.

The $4.4 million request for Hard Rock Penetration research includes tests on new drilling bits and the development and field-testing of a prototype advanced drilling system on a cost-shared basis with industry. The $1.4 million request for Magma Energy Extraction research will include the identification of reservoirs suitable for the extraction of energy from molten rock and evaluation of materials that can operate in the harsh magma environment.

In Geothermal Technology Transfer, the request of $1.0 million will be used for a variety of activities including conferences, seminars, publicatons, and cooperative technology reviews to improve knowledge sharing with the geothermal research, development and industrial community.

GEOTHERMAL RESOURCE DEVELOPMENT FUND

The Geothermal Resource Development Fund (GRDF) was established to broaden the geothermal energy technology base through guarantying risk capital for private sector development of several state-of-the-art facilities. The $0.1 million budget request allows for evaluation of pending loan applications, restructuring of existing guaranty agreements and monitoring outstanding loans.

HYDROPOWER

Small scale hydropower is a comparatively mature technology that uses the nation's streams and smaller waterways as an energy source to produce electrical power. The FY 1985 budget request is $0.5 million. The DOE program will focus on monitoring a number of hydropower projects funded through prior years and transferring the results of those projects to the non-federal community.

CONCLUSION

Overall, the budget submitted for Fiscal Year 1985 represents a balanced and objective approach to sustaining the momentum achieved in conservation and renewable energy development. The balanced research and development program includes public and private cooperation and effective technology transfer efforts to enhance the national ability to define, develop and implement conservation and renewable energy technologies. Their development is consistent with the goals and objectives of the Fourth National Energy Policy Plan.

I thank you for the opportunity to make this presentation today.

ATTACHMENT

U.S. DEPARTMENT OF ENERGY FY 1985

CONSERVATION AND RENEWABLE ENERGY
(Budget in $000s)

	FY 1984 Budget Request	FY 1984 Appropriations	FY 1985 Budget Request
ENERGY CONSERVATION			
Building and Community Systems	$ 16,385	$ 37,408	$ 35,314
Industrial	10,633	33,712	33,294
Transportation	40,957	65,038	51,052
Electric Energy Systems and Storage	26,902	44,200	35,335
Multi-Sector	3,102	12,777	26,548
Subtotal - Conservation	$ 97,979	$193,135	$181,547
SOLAR ENERGY			
Solar Building Energy Systems	10,450	16,450	11,885
Photovoltaic Energy Systems	32,700	50,400	47,500
Solar Thermal Energy Systems	11,500	43,850	37,500
Biofuels Energy Systems	17,300	28,400	28,100
Wind Energy Systems	8,600	26,500	23,300
Ocean Energy Systems	0	5,500	3,500
International Solar Energy Prog.	0	500	500
Solar Technology Transfer	3,100	3,250	6,000
Program Support	0	800	500
Program Direction	3,009	6,000	4,864
Subtotal - Solar Energy	86,659	181,650	163,649
GEOTHERMAL ENERGY			
Hydrothermal Industrialization	0	2,000	0
Geopressured Resources	0	5,000	3,500
Geothermal Technology Development			
Hot Dry Rock	5,040	7,540	5,500
Hydrothermal Research	4,434	11,334	10,056
Hard Rock Penetration	2,640	2,640	4,600
Magma Energy Extraction	845	845	1,400
Geothermal Technology Transfer	100	100	1,000
Program Direction	494	1,000	1,031
Subtotal - Geothermal	13,553	30,459	27,087

U.S. DEPARTMENT OF ENERGY FY 1985

CONSERVATION AND RENEWABLE ENERGY
(Budget in $000s)

	FY 1984 Budget Request	FY 1984 Appropriations	FY 1985 Budget Request
HYDROPOWER			
Small-Scale Hydropower Devel.	0	500	375
Program Direction	0	250	72
Subtotal - Hydropower	0	750	447
Subtotal - Renewable Energy R&D	100,212	212,859	191,183
GEOTHERMAL RESOURCES DEVELOPMENT FUND (GRDF)	2,100	2,100	121
GRAND TOTAL	$200,291	$408,094	$372,851

Senator **Evans**. Thank you, Mr. Collins, for a good review of a very difficult and extensive program. I am sure we will get into some of the areas that you spoke of a little more in detail with the public witnesses who will come afterwards, but let me start with a sort of a fundamental question I have asked of a number of other witnesses in the energy research and development field, and perhaps I will find an answer. I haven't yet.

In the work that you do and the work of those of your colleagues in relationship to the energy research and development, how do you make a determination on a continuing basis of the relative priorities and how you assure that we are keeping some balance in the priorities of research and development in the energy field?

Mr. **Collins**. Well, Senator Evans, I think that is possibly one of the most difficult aspects of this position. Let me just describe the way we approach it.

Basically we are dealing with over 500 particular items of research and 1,400 contracts. Within the framework of the National Energy Policy Plan, Secretary Hodel has set off what he thinks may be a significant change in energy mix in this country. We don't know exactly where it is going to come from, and of course, many of our States are fortunate to have energy resources that are more than entire countries in this world. So we are pursuing a great many activities along this line.

Basically, however, we are pursuing those in this budget that we think are basic and applied or proof of concept. Where our work is closing in on commercialization, we let the private sector make the choice to go or not go with that project at that point in time.

I certainly think that this is a flexible document. I had just a couple of months to work on it before it was closed on in the administration. I have learned some things since. Although our numbers are very similar to the numbers appropriated by the Congress last year, the programs are not all the same. I think as the Energy Research Advisory Board said, we are going to have to take each one of these 500 and some technologies and either sooner or later the commercial sector can decide to make a go or no go decision. That is where the tough judgment call comes. That is one of the reasons that we have this fellowship program and the technology transfer program, is to get the State and local officials, to get the private sector and university sector involved in that decision.

Senator **Evans**. Tell me about the activities of the Energy Research and Advisory Board, not its membership necessarily, but the kind of people and how often they meet and with whom.

Mr. **Collins**. I have had the opportunity—it is relatively new to me being in the Department—I have had the opportunity to meet with them twice. This Board is assigned technical tasks where they can provide the expertise. They are esteemed professionals in the field, and they provide technical analyses of the task that the Secretary assigns to them.

As I said, I have read every single one of their monographs back to 5 years ago in the conservation and renewable area, and I feel that, for example, in this particular area, we are consistent with them on almost every recommendation. I hope that we can continue to do that as well.

Senator **Evans**. How often do they meet?

Mr. COLLINS. I think they meet whenever a specific task is assigned. I don't think that there is a set meeting time per se, but I would like to provide that for the record if I may.

[The information follows:]

ENERGY RESEARCH ADVISORY BOARD [ERAB]

The Energy Research Advisory Board (ERAB) advises the Department of Energy on various research and development matters. Its membership averages 25 persons, and consists of high ranking and respected members from the private sector and university community. The Board holds four regularly scheduled meetings per year.

From time to time, however, the Secretary of Energy may transmit instructions by letter to the Chairman of the ERAB requesting investigations of a specific issue to be conducted and completed within a prescribed period of time. A temporary panel is then convened, made up of several ERAB members and other non-Federal experts on the issue under review. The panel meets as often as necessary to gather and analyse information, and conduct deliberations on the subject in question. The results of the investigation are published in a final report, which is presented to the ERAB Chairman, who then forwards the findings to the Secretary of Energy.

Senator EVANS. All right. That's fine. I guess in my question on the priorities I would go beyond just those current programs that are as you described here, the basic research and bringing something to the point of potential practical use where admittedly the private sector ought to be able to take over at least largely, but how, to what degree do you have any interrelationship as you develop these research budgets with say the Synfuels Corporation, with the amount of money that is set aside for it?

Mr. COLLINS. Well, I find that there is a significant amount of dialog within the administration. There are some formal groups, for example, the Hydrogen Energy Coordinating Committee, and others, that have been established clear back to the early days and have been continued, with the other agencies vis-a-vis Synfuels, in this case, in which there are discussions within the administration. I think that you probably never can coordinate enough in those areas, and I have had several suggestions from the House and Senate side as well about the coordination between DOE and the Synfuels Corporation. We have tried to work those out with the various Members of Congress who have brought them up.

I find that we have a great deal of conversation with the Chairman of the Synfuels Board, and with the staff, and we find, we feel that we are fairly knowledgeable on both sides along that line, Mr. Evans.

Senator EVANS. With the admittedly tight budget, we are all spending time on the floor, you know, over the last several weeks and will over the next month probably, trying to figure out how to make even a dent in the current deficit, so we will have limited funds.

Does anyone ever specifically look at those moneys already appropriated to decide whether in fact what appeared to be the reasonable priority of the year or two or several years ago still is valid? And let me get back to that same example.

As I understand it, we have authorized the spending of up to $14 billion through the Synfuels Corporation. That was several years ago.

Do we still think that is where we ought to spend $14 billion as compared with research and development in other areas? Has anybody ever really taken a look at that?

Mr. COLLINS. I think, Senator Evans, I am getting a little bit afield from the expertise I have been able to get in the last 7 or 8 months, but I do think that——

Senator EVANS. Don't let that bother you. We do it all the time.

Mr. COLLINS. I think that we have been focusing in that area on knowing that that money was available and knowing what the progress should be. We want to progress as effectively as we can, but at the same time not actually just getting involved writing all the checks immediately for projects that may be there without a strong look at the cost effectiveness.

I have been extremely pleased with the cooperation we have gotten from the Members of the House and the Senate on this budget and in talking about projects that have not proceeded as quickly or as successfully as we would like, or those that took off and went faster. This is probably the most, creative part of the entire Department of Energy budget, and we have been extremely flexible on discussing it with the Members of Congress, and we in return have found a great deal of flexibility up here.

I haven't seen a better relationship than we have had, in my experience of 7 years up here.

Senator EVANS. What about all of the things now going on? If at this point you could pick out one or two of the most promising arenas, what would you pick given what we know right now?

Mr. COLLINS. This is always difficult because we have so many people with expertise. We are working on a long-term plan and just went through 300 different research possibilities in the renewable field alone, but I think everyone is to some degree focusing on photovoltaics as being a potential strong candidate for commercial success and widespread application. There are others that in the long term could be outstanding, but we don't seem to quite be there yet. There are some others that I think progressed even faster than we thought, and they are ready probably for the commercial stage. I think you will have some witnesses later about some of those. Certainly in that area there has been a great deal of progress, as there has been and in some of the work that we are doing in hydropower. As you know, the number of applications for licenses and permits has increased 40 times since 1977 and of course, a lot of those are for small hydro projects. I think that certainly in the industrial area, and in the transportation area there are some exciting possibilities that we could make progress on such as ceramics and tribology and other basic sciences like we emphasized in this budget, Senator.

Senator EVANS. On photovoltaics, you talking in your paper about the experiment efficiencies recently attained of 22 percent. I presume that is laboratory efficiencies?

Mr. COLLINS. Yes, sir.

Senator EVANS. And looking ahead to 35 percent, what do you anticipate as a percentage of efficiency that would make photovoltaics essentially cost effective compared to the other sources?

Mr. COLLINS. Basically in our photovoltaics work, costs have improved about 10 times in the last 10 years, and if it improves that much again, it will be in the area where we think it is cost effective. I think that being able to produce this in a mass fashion will make that more successful.

I think I would like to, as far as a prediction, call on Dr. San Martin for a suggestion of what the percentage would be if I may.

Senator EVANS. Fine.

Dr. SAN MARTIN. Mr. Chairman, there are many different types of photovoltaics, concentrating systems, et cetera, and therefore, there is a different amount of materials complexity involved in each, so that there isn't a single efficiency that I believe applies to all systems in making that determination.

Flat plate photovoltaics systems, of the type that are predominantly marketed today, have targeted efficiencies slightly in excess of 15 percent, which we believe will make them more attractive and have a much greater market.

When we look at thin film photovoltaics, achieving efficiencies on the order of 10 to 12 percent combined with mass production should make them a very, very attractive energy source.

When we are talking about the very high efficiency photovoltaic devices which Mr. Collins referenced, attaining conversion efficiences in the more complex systems of 30 to 35 percent is going to make them very attractive. So the efficiency correlation, as you can tell, varies depending on the inherent type of device, the amount of materials that are utilized, and the complexity of the system it represents.

Senator EVANS. When you say very, very attractive, does that mean cost effective currently?

Dr. SAN MARTIN. Mr. Chairman, there are places today where photovoltaics are being sold and they are cost effective today. Those markets happen to be fairly small.

When you and I are talking of being cost effective, we normally mean cost effectiveness the broad market that is, most any place within the United States. That is an incremental, evolutionary process, and the types of efficiencies that I quoted would allow that to occur.

Senator EVANS. Mr. Collins, just to back off and look in a broader sense at the conservation side of things, there are some who suggest that greater efficiencies in the use of all types of energy alone could handle our energy needs for essentially all of our energy needs for the rest of the century.

What is your opinion, what is the Department's opinion of that? And if you disagree, then how far can we go with that?

Mr. COLLINS. Well, Mr. Evans, I think that quite frankly, we use some ranges in the National Energy Policy Plan. We talked in the neighborhood of 10 to 13 percent in the early twentieth century. I think that, quite frankly, when you look at the potential that we all know is extremely large, and we are talking about geopressure and some of the work which is currently in the experimental stage, it depends on the price of petroleum and other energy sources. How fast that will be pursued, some people suggest that could be doubled in a fairly logical scenario, but I think that based on current assumptions that 10- to 13-percent range would probably be accurate.

Senator EVANS. Ten to 13 percent of new energy requirements to be met in conservation?

Mr. COLLINS. Of those needed in the years 2000, 2010, in that decade, sir.

Senator EVANS. Is that 10 to 13 percent of the difference between where we are now, and in the needs of that year?

Mr. COLLINS. No, sir; overall.

Senator EVANS. Overall?

Mr. COLLINS. That would be about double in essence what we are talking about.

Senator EVANS. I was going to say, you assume that 6 or 7 percent now?

Mr. COLLINS. Yes, 6 percent in the renewable areas, Mr. Evans, and I would like to—six quads, yes—to defer to Miss Fitzpatrick if I may on that.

Senator EVANS. I am really not talking about renewable. I am talking about just conservation, better efficiencies.

Miss FITZPATRICK. Mr. Chairman, I think in the last 10 years, figures show that we have increased our energy efficiency, that is, exercised conservation, by about 20 percent. If you take gross national product against energy consumption, and that has been driven in large part, of course, by the increase in the basic fuel prices as we referenced earlier, we think that that can be improved upon definitely.

We have examples of industries or companies that have paid attention to their energy use, have made the 20-percent difference and now say they think they can double that. Whether that can be done across the board, of course, remains to be seen.

We are working on technologies as we mentioned in transportation, for example, which would produce, if successful, a 30- to 40-percent increase in efficiency.

Secretary Hodel has often used the image of pushing back the wall of energy use. We hit it at dozens, hundreds of points, and keep trying to push it back. We do see opportunities in one area after another where we can make increases of 20, 30, 40 percent just in using the fuels that we are using now. This is aside from bringing on new alternative fuel supplies.

Mr. COLLINS. Mr. Evans, if I may add to that, sir, in the Federal Government alone we have a goal of a 20-percent increase in efficiency from 1975 to 1985. Secretary Hodel and I think there is probably another 10 percent beyond this that we can find within the Federal Government system. In industry there has been a 23 percent improvement in energy use per unit of output, and I think that we have some companies who have already made 30 percent improvements in the last decade and are now going for 20 percent more. So we think there are some outstanding possibilities not only in the Federal Government but privately, and certainly in the industrial sector where most of the faster progress has been made.

Senator EVANS. You talk about transportation efficiencies and the potential to increase those substantially with new technology and all of the work that you described in here as being sponsored and done.

Will you agree that probably the largest single conservation element of the last decade was just in setting standards and goals for automobile efficiencies, the Government doing nothing more than saying they had to meet them and let private industry figure out how?

Mr. COLLINS. Certainly a great deal in the petroleum area.

Senator EVANS. That is what I am speaking of now, particularly in the petroleum area, and transportation.

Mr. COLLINS. We certainly think that, quite frankly, the individual citizen and the economics of the individual family have had a great deal to do with this. The fact of the matter is, however, we do find that permanent conservation ethic which I think you are alluding to in the last 2 years where petroleum prices have stabilized, and quite frankly, the conservation has continued. We are a little bit concerned about some people taking their eye off the ball at this point in time. When you are talking about 60 percent of our petroleum use or 61 percent, and about 27 percent of our overall energy use, it is an extremely important category, and we are looking very, very carefully at which mix of stimuli are needed to be successful.

Senator EVANS. What is the administration's view then currently on that mix rather than spending more money, doing a lot of esoteric research at the Federal level or sponsored by the Federal Government? Why not just raise the automobile efficiency standard to 35 miles a gallon?

Mr. COLLINS. A great many Members of Congress have certainly brought to our attention the many, various factors that affect us. We have not closed, quite frankly, in the administration on this, and we are working on it presently.

Senator EVANS. Have you looked at all—turning to the electrical section for a moment, in developing the Northwest Electrical Powerplant the last couple of years, we found that even with the extremely high growth scenario for the next 20 years, one that is far faster both in terms of population and the economic than I think any of us expected in the Northwest or even hoped for—we don't want that many people—it will require more than doubling of the population to meet a high growth line, and yet we have found that more than 60 percent of that, of that enormously increased electrical energy use, could come simply from conservation, and the low growth which is essentially where we are now showed for the next 2 years nothing but conservation would handle all of the new electrical needs for that growth period.

One of the most interesting developments was in trying to find out from industry what they could do and having them respond that it was far too complex, that there was no way to model, lots of reasons for not suggesting any large amount of conservation until we asked them what could you come up with if we paid $1,000 per installed kilowatt, just because that is a whole lot cheaper than the cost per installed kilowatt of building? And they are minimal. You would be astonished at the amount and ingenuity of energy conservation that came back as a result.

Has anything like that been done or in process at the national level to give us a clear idea of what is available out there?

Mr. COLLINS. We are certainly taking a long, hard look at that. I happen to live within that same area and am serviced by that, and my last trip home I was able to attend and be briefed on some of the incentives that they have with the building community.

I think it is extremely exciting, and we are reviewing that certainly in this budget. For example: technology transfer; we consider that an integral part of this. There are some incentives that are being offered there that are unique.

As you say, some of the projections that we had say 5 or 10 years ago have not proven to be accurate. There are some outstanding potentials, and I know that there has been a great deal of discussion, some of it relatively exercised, in the Northwest about the pursuit of this. We are pursuing every single thing that they are doing in the Northwest plan with an eye toward whether it could be cost effective in the national sense, sir.

Senator EVANS. We have been joined by Senator Levin. Senator Levin, do you want to use up all the time? Do you have some questions of Mr. Collins and his colleagues? I will be happy to yield to the Senator from Michigan.

Senator LEVIN. Any time, Mr. Chairman.

Senator EVANS. Why don't you go ahead now? I will take a deep breath and think of some more.

Senator LEVIN. Welcome, Mr. Secretary. Although we are discussing the Research and Development Program for the Energy Department, I would like to just focus on a portion of the energy budget which you are in charge of, which is of great concern to me. That is two programs—weatherization, school and hospital grants, which are to be funded out of a speculative source.

The administration is proposing to fund three programs out of the Petroleum Overcharge Restitution Act, and nobody knows whether that act is ever going to be adopted. As a matter of fact, I checked around with the staff here. It is pretty unlikely at least in their prediction, that there is a lot of support for it among the Senators that they work for, so that would mean if this act doesn't pass, that three critical programs would not have funding. Again, we are talking about the weatherization program, schools and hospital grants, and low-income energy assistance.

Now according to the Secretary at an earlier hearing, the DOE expects oil overcharge recovery, assuming that the act passed, of $5 to $6 billion over the next several years.

If the legislation does not pass, the administration request for weatherization and schools and hospitals would be zero. Apparently the administration has yet to decide what they would request for low-income energy assistance.

Now our statistics show that since the inception of the weatherization program, more than 1 million homes have been weatherized. The DOE in its budget submission estimates that the $190 million request for this year would weatherize approximately 190,000 additional homes. By the way, in my own State of Michigan, in fiscal year 1983, 18,000 needy homes were weatherized, bringing the total for the State to 66,000 residences which have been weatherized through this Federal program, and about two fifths of these houses have been inhabited by the elderly, so this program is important in this country.

I presume you would agree these are important programs? Is that fair to say?

Mr. COLLINS. Yes, sir.

Senator LEVIN. What is going to happen if the act doesn't pass? Doesn't that just jeopardize a good program?

Mr. COLLINS. Well, Senator Levin, I think that this was certainly brought to our attention, and when I first came on board about the second month I think this fall, I was at a meeting of all the State energy directors in the Midwest, and I think it also happened to be brought to our attention by one of your constituents because one of the most poignant letters that the Secretary and I received this last year was from one of your constituents about the necessity for this.

What the State energy directors told us in in the fall is that, notwithstanding the fact that the administration had proposed a $1,200 million in the low-income assistance program through the HHS, they were concerned about the continuity and stability of this program. They were concerned as professionals in administering the program, and they were concerned for the constituents of this program.

We reviewed the situation and, of course, having worked up here 7 years I had seen that there was a steady level of support in the Congress for these programs, and I mentioned that.

In addition, I mentioned to the Secretary the concern of the professionals in this field for this continuity and stability. So what we have suggested is a 5-year commitment, over $2 billion a year, with funding in two programs that has not been suggested by the administration in the last 3 years, the schools and hospitals and the weatherization program, which would provide money from the general funds if we are not successful in those lawsuits. If we do not bring in as much money as has been held in many instances, if that money is slow coming in because it is appealed through the court system, instead of having the staff either to wait for a large pot of money to come or to bring in new staff to administer that pot, in essence that money would be brought down on a regular basis over a 5-year period for these three important programs, two newly suggested in the funding in our budget by the administration and one enhanced from $1.2 billion to $1.875 million.

We think for the professionals and for those that are receiving the help, that that 5-year commitment and the stability of payments because they are predicated on the general funding and not on the speed and success of lawsuits, is very helpful in this area.

Senator LEVIN. I am not sure what you are saying. It seems to me the program is built on sand if we are relying on funds that are recovered under an act which hasn't passed.

Are you saying that whether that act passes or not, that these programs are going to be funded at the same level?

Mr. COLLINS. The present position by the administration is if that act is passed, those three programs would be funded at the level that the Congress passed last year, pretty much the level that they have supported in the last three.

Senator LEVIN. Do you expect this act to pass realistically?

Mr. COLLINS. We are working as hard as we can on it.

Senator LEVIN. Do you expect the act to pass realistically?

Mr. COLLINS. Having worked up here 7 years, I am loathe to make predictions about anything like that.

Senator LEVIN. What happens if the act doesn't pass?

Mr. COLLINS. I think we will address that at that point in time. We are talking about the 1985 budget, of course, and we——

Senator LEVIN. You are not committed to continue these proposals if this act doesn't pass?

Mr. COLLINS. Sir?

Senator LEVIN. You are not committed to continue these proposals if this act doesn't pass?

Mr. COLLINS. I think that is something that we would address if the Congress decides not to take action on this. We are working as hard as we can.

Senator LEVIN. I want to know whether you are committed right now. Is the administration committed right now to continue these programs whether or not that act passes? It is a straightforward question.

Mr. COLLINS. I think that has not been addressed, as I understand it, and we are waiting for a sign that the final action is going to be taken one way or the other here in the Congress.

Senator LEVIN. Is it fair to say that you are not committed at this point to continue these three programs whether or not that act passes?

Mr. COLLINS. I wouldn't say it that way, Senator Levin.

Senator LEVIN. You either are committed or you are not committed. There is no use mincing words on me.

Are you committed at this point or aren't you? The answer is either yes or no.

Mr. COLLINS. At this point we are working with the Congress on the petroleum overcharge restitution fund and putting all of our energies into that proposal at this point in time.

Senator LEVIN. Everybody acknowledges that that is an if-come. You acknowledge it is an if-come. You don't want to speculate on it yourself. You are not sure it is going to pass. You are not even confident it is going to pass. I am pretty confident it is not going to pass.

Putting that aside, you can't say with any degree of confidence that it is going to pass? You can't predict it is going to pass. You are loathe to make predictions and you are right. You shouldn't make predictions. We have three programs here that are pretty important in this country that shouldn't be based on sand, and on speculation.

Now my question is, and I am going to keep asking it because I think it is a fair question, if the act doesn't pass and no one can predict with safety that it will, will those programs fall? Is that the administration's position now?

Mr. COLLINS. We don't have a position on that point, at this point in time, Senator Levin.

Senator LEVIN. When will your position be clear on that point? Give us a month.

Mr. COLLINS. I think a great deal depends on congressional action.

Senator LEVIN. If the act isn't passed by September, will your position be clear by then?

Mr. COLLINS. I think that the position of the administration right now is that we are working as hard as we can with the Congress to make sure that that legislative proposal passes, and that is the only final position that we have at this point in time.

Senator LEVIN. Well, Mr. Chairman, I think the committee and the people of the country are owed more than that on three programs which everyone agrees have been successful.

Can we at least get that clear on the record? Do you agree these programs have been successful?

Mr. COLLINS. Certainly these programs have assisted a great many people. Some of them we wished were administratively tighter in certain areas and we are working on that as well.

Senator LEVIN. Would you like to see these programs continued?

Mr. COLLINS. I think that these programs have done a great deal of good for many individuals that I have had an opportunity to talk to.

Senator LEVIN. Would you like to see the programs continued?

Mr. COLLINS. As they are presently constituted, if we can establish the continuity and stability that was requested in essence by the State energy directors and the weatherization people who were at our fall meeting, I think that would be the best possible for all the people involved.

Senator LEVIN. You can't say yes or no that you would like to see these three programs continued?

Mr. COLLINS. I would like to see them continued, yes, sir.

Senator LEVIN. Just a change of subject then—I have used probably more time than I should. To switch you back to a different area, the area of wave energy, it is my understanding that there is some really exciting research being done in wave energy at this point, and that it could use some further funding from the DOE.

Can you tell us why you haven't proposed funding for wave energy, No. 1, and No. 2, if we decide to put some funds in there for R&D for wave energy, would you be willing to enthusiastically carry out that appropriation?

Mr. COLLINS. Certainly we are going to enthusiastically carry out every appropriation that we get from the Congress as signed by the President. We feel very strongly about that. Both the Secretary and I do.

Certainly in wave energy we have had several opportunities from some proposals by companies in your State, for example, in the Great Lakes area, to do ocean thermal type of projects, particularly in the State of Hawaii. We have pursued, along with the Solar Energy Research Institute the programs by companies from your State and others, and we are reviewing all of those at this time.

Initially I might say that there are a great many problems in this area with biofouling and some other technical difficulties, but I have looked into them personally in the 7 or 8 months that I have been here, and I think that it is part of the mixed and balanced resource system that we think we ought to pursue in general.

Senator LEVIN. My last question, Mr. Chairman—is it your understanding and feeling based on what you do know and the information that has been brought to your attention if we did find some funds for research and development in the area of wave energy that they could be usefully spent?

Mr. COLLINS. Certainly we would. We have done that in the past, and we would continue. We are reviewing a variety of proposals, some of which may be very promising, and we would spend them extremely effectively I am sure, Senator.

Senator LEVIN. Thank you. Thank you, Mr. Chairman.

Senator EVANS. Thank you, Senator Levin. Let me ask a little about hydrogen energy.

In looking at energy research and development, it seems to me one of the places we should start is seeing what can be done to—well, let me back off and ask another question first.

To what degree in your work have you tried to examine the full costs, including the direct environmental costs of various forms of energy production in order to get a clear picture of the true economic costs and the economic comparison between various forms of energy production?

It seems to me that the first step that you almost have to go is in terms of knowing what appears to be the most productive direction of research.

Mr. COLLINS. Yes. Senator, we do an economic and technical analysis of every program and try to look ahead to the cost effectiveness of it, and certainly the environmental and public health aspects of the program.

You certainly can get much stronger numbers in certain areas than you can in others, but the Secretary and I are committed to pursue the most environmentally satisfactory as well as cost-effective avenues in the conservation and renewable areas, and in general I think that is reflected in this budget.

Senator EVANS. I go beyond that. In terms of your looking at what is now current in the field or current standard methods of energy production, do you feel that we are in every case assigning full cost to that energy production?

For instance, in the burning of fossil fuels, are we assigning the costs of environmental protection to the degree we should be?

Mr. COLLINS. I think that that is an extremely difficult analysis in many instances, Senator Evans, and I have worked on that for over 10 years, and I certainly think that to the degree possible, we do pursue this.

We have a great deal sometimes of different views within the professional career scientific community along these lines, and so we have to weigh those along with some economic factors that can be attributed to these analyses.

I have experienced that working with the Congress for an awfully long time, and I find it an imperfect process unfortunately, but we do it the best that we can.

Senator EVANS. Does the administration or do you at the current time assume that some of the proposals on reducing SO_2 emissions from a coal-fired plant in terms of reducing acid rain is yet proven or necessary? What is the position on that?

Mr. COLLINS. Senator Evans, there is a great deal of disagreement presently.

Senator EVANS. I know there is a great deal of disagreement. What is the administration's view?

Mr. COLLINS. Quite frankly, since there is such a significant amount of disagreement from the professional career scientific community within the Government and even within agencies within the Government, I think that our proposal to in essence more than double the research in this area is the way to go at this point in time. My father spent almost 30 years in the Government in the scientific area, and that is not overly strange in my experience.

Senator EVANS. Do you have any doubt at this moment that that phenomenon of acid rain is there, and that it has increased at least measurably over the last 10 to 20 years?

Mr. COLLINS. Well, I think that there is a great deal of disagreement among our career scientists on that, and I would like to outline that if I could in depth to some degree for the record if that would be possible?

[The information follows:]

ACID RAIN

The phenomenon of acid rain is real. However, the fact that rainfall is acidic is not necessarily disturbing unless we can correlate acidity with substantial adverse effects. The link between the acid rain and the severity and distribution of adverse effects is still being determined. Indeed, in the case of observed forest damage, it is currently uncertain whether that damage is strongly linked to acidic deposition or to other causes such as ozone, trace metals, drought, or "all of the above."

While there is disagreement among our career scientists on many of the issues concerning acid rain, many agree that as William Ruckelshaus, the Administrator of the Environmental Protection Agency, said in testimony before the Senate Committee on Environment and Public Works, there is acid rain, it is a problem, and a solution to the problem is desirable. Unfortunately, the information and understanding of the phenomenon is such that it is unclear what the appropriate next steps in terms of public policy should be. We do not even know whether the future will show fewer effects, greater effects, or no change under current regulations. The limited available data suggest that there has been an improvement in water quality over the last ten to fifteen years in the northeastern United States. This gives us hope that the decline in emissions that has taken place since implementation of the Clean Air Act is resulting in water quality improvement. However, the available data are too sparse to generalize with confidence at this time. Therefore, more research should be carried out before we decide on what kind of response is appropriate.

Senator EVANS. All right. That would be fine. Questions will be asked—not only that question which was whether you felt there was in fact a phenomenon I guess known as acid rain and whether it had deleterious effects? And having determined that, then of course, the next question is current views as to cause and correction.

On the nuclear side, do you feel that we are adequately including in the cost of nuclear energy the costs of long- time storage of spent nuclear fuels and the decommissioning costs for nuclear powerplants?

Mr. COLLINS. I certainly say that that is generally beyond the area which I concentrate in.

Senator EVANS. I understand that. I understand that it is, but I guess what I am trying to get at is in looking at energy research and development, in even making a determination when something is getting close enough to, you know, to economic cost or cost effectiveness so that you can turn it over to someone else for production, you have to know what the cost effectiveness is, and that is what I am trying to get at is whether we are currently or if you are doing anything to even determine what the accurate total costs of production of current forms of energy are?

Mr. **Collins**. My understanding, Senator Evans, is that we are where it is quantifiable, and we are trying to make the best judgments possible, and certainly with a great many caveats. That is one of the reasons that in our national energy policy plan we used a range in many instances, because there are so many variants along that theme.

I would like to also submit possibly some more on that for the record, but we are, both the Secretary and I believe, to the point where we are pursing the research plan for the technologies involved in this budget, Senator Evans, to the year 2000 and 2010 because we think that long-term planning is absolutely essential to figure out What you should do in the short term on a cost-effective basis.

[The information follows:]

TOTAL COSTS OF PRODUCTION

Several attempts have been made in the past to determine the costs of production of various technologies and studies have addressed the costs of specific externalities such as the need for pollution equipment and waste disposal. However, as you are aware, comparisons of future costs and externalities across technologies and across fuel types are difficult to do with any degree of confidence.

However, the Department will continue to address broad systems issues that may affect our energy use, including the hazards and environmental costs associated with energy production and use.

A copy of the Department's "Energy Projections to the Year 2010," [1] which addresses these issues in its projections, is being provided to the Committee.

Senator **Evans**. That gets me back to the question I started to ask. It seems to me that in looking at energy research and development, of course you want to broaden your scope and the very nature of research is to search and to try to find not knowing before you start what is going to be the most likely resources, but it does seem to me that one of the things that would be useful is to try to describe the goal, and the goal would be obviously an energy source which is cost effective, hopefully gets cheaper as time goes on if we can be that lucky, but also one which is environmentally benign to the maximum degree possible, and has, you know, all of the other elements and the attributes that make it as close as possible to the perfect energy source.

With that in mind, it seems to me that one of the potential areas would be in the effective development of hydrogen energy which sure has a whole lot less environmental problems. Nobody is going to accuse the burning of hydrogen might produce acid rain. It might produce rain, but it won't be acid, and it won't need long-term nuclear storage and a lot of other elements that go with other forms of energy production, and yet I see little attention or little emphasis paid to hydrogen energy research. Why?

Mr. **Collins**. Well, sir, I think that in the Department of Energy budget alone we are talking in the neighborhood of $20 million in at least four different areas of the Department.

We are extremely interested in hydrogen, and of course, it is very exciting as a possibility for the long term. We certainly recognize your leadership and that of Senator Matsunaga in this area, helping us focus on it.

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[1] Retained in subcommittee files.

There are some significant problems in the short term that we are trying to address and which I think will be addressed if this budget is adopted. Certainly we are concerned about because the problem with storage, probably losing a third of it just transporting it from Louisiana up to NASA. Also the brittleness of the system components is being looked into, and of course, that is one of the reasons that in our budget we are looking at ceramics and such basic research activities as that.

Hydrogen is, I think, probably the one energy source that we all look at as sort of the ultimate in many, many ways. Getting across those first few hurdles seems to be difficult, but we are pursuing them relatively vigorously and spending a significant amount of money in the proposed budget and last year's budget.

Senator EVANS. Sometimes it seems to me that the goal we are attempting to achieve, $14 billion in the synfuels program, that much money could product almost anything in any other program.

We will have some questions for the record. You have mentioned several that would be useful for you to be able to answer in written form.

I would like to ask for the record what some of those short-term problems are in the research area in hydrogen energy, and we will have some other programs very likely. I want to wait until we hear from the other witnesses on some of the specific programs they are going to deal with. As a result, I haven't asked questions in wind energy and some of the others, but we may have some written questions for you.

Mr. COLLINS. Thank you very much, Senator.

[The information follows:]

PROBLEMS IN UTILIZING HYDROGEN

There are three major problem areas for utilizing hydrogen in today's economy. These relate to hydrogen production, storage and transport. Each is discussed below:

(1) Hydrogen Production: There are inherent inefficiencies of converting a primary resource to a secondary energy form such as hydrogen. The focus of the program within our Office of Energy Systems Research is to achieve maximum energy conversion efficiencies which can equate to hydrogen production cost savings. The energy requirements for dissociating water can be in the form of heat and/or electricity. Since there are efficiency limitations of steam cycles used to produce electricity, it would appear prudent to pursue the direct utilization of heat in water splitting processes. Operating in the extreme temperature regimes ($> 3000^{\circ}C$) does not bode well with regard to materials availability and process simplicity. Substantial efforts in the past have been directed toward identifying thermochemical cycles which could alleviate some of the process engineering difficulties; however, materials handling, corrosion, and process complexity remain major problems.

There is a compromise by utilizing both heat and electricity in water vapor electrolysis processes. Current projections indicate that the electrochemical dissociation of water in the $300^{\circ}-1000^{\circ}C$ temperature regime can result in process systems operating at 40%-50% energy efficiency, a substantial improvement compared to conventional water electrolysis systems which operate at 25% to 30% energy efficiency.

Other options for reducing electric energy requirements would consider depolarization mechanisms, especially at the oxygen evolution electrode. One strategy is to consider the co-production of hydrogen and a valuable chemical commodity that would result from the direct or indirect oxidation of selected chemical species.

(2) Hydrogen Storage: Current practice identifies compressed gas and liquefied hydrogen as the primary storage options. These storage systems do not lend themselves to bulk long-term or mobile short-term storage applications necessary if hydrogen is to assume an expanded role in the future U.S. energy infrastructure. Advanced storage systems must seek out high-storage-density, energy-efficient, low-cost, and safe alternatives.

(3) Hydrogen Transport: One means for hydrogen's penetration of the energy infrastructure is via the natural gas supplementation option. In other words, if we could transport hydrogen together with natural gas in existing natural gas lines, it would bring the use of hydrogen a great deal closer. In order to use this option, it is necessary to establish the compatibility of hydrogen with conventional pipeline steels by quantifying any suspected problems under field use conditions. If necessary, protective measures for ensuring the safe and effective transport of hydrogen via available pipelines will have to be investigated.

Senator EVANS. Thank you very much. You have been here for an hour, and we appreciate very much our testimony.

Mr. COLLINS. Thank you very much.

Senator EVANS. Next, the public witnesses, if they would all come up as a panel—Alvin Hildebrandt, Frank Duquette representing the Solar Energy Industries Associates from Huntington Beach, CA; Dr. Stuart Ridgway, program manager, Mist Heat Engine, R&D Associates from Marina del Rey, CA; William D. Lang, vice chairman, Energy Committee, Institute of Electrical and Electronics Engineers; J. Hilbert Anderson, president of Sea Solar Power, York, Pennsylvania, and Dr. Lloyd Lawrence, Jr., director, Technical Development, Mechanical Technology, Inc., from Latham, NY.

I understand that Mr. Hildebrandt has another appointment, and we would like to take you first.

STATEMENT OF ALVIN HILDEBRANDT, ON BEHALF OF THE SOLAR THERMAL DIVISION, SOLAR ENERGY INDUSTRIES ASSOCIATION

Mr. HILDEBRANDT. Thank you, Mr. Chairman. I am Alvin Hildebrandt. My testimony is submitted on behalf of the Solar Thermal Division of the Solar Energy Associates whose members have placed the United States as the world leader in the solar thermal technology.

This leadership is based upon a momentum gained through the 1970's beginning with the early efforts of the National Science Foundation, and continuing thereafter with the support of ERDA and the Department of Energy. Over 10 years of cooperative, federally supported industry programs have led to the development of advanced systems that have exceeded nearly all performance expectations. The transition from early proof of concept and test prototypes to full-scale operating systems for industrial and utility users is almost a reality.

Detailed testimony for the record is provided in the attached document of Mr. Frank Duquette and myself, and I will limit my comments to several of the most crucial items.

Senator EVANS. The full statement will be included in the record.

Mr. HILDEBRANDT. Thank you, Mr. Chairman. Over the past several years the solar thermal industry represented the view that no more than a few years of additional direct support of the major solar thermal technologies would be required in order to complete DOE's programs for base technology and system-level engineering. We believe this was a reasonable assessment based upon a series of assumptions on the market environment which did not or had yet to materialize. These assumptions were an increase in oil prices rather than the current prices at historically low levels, expectations of funding for DOE-supported solar thermal activity at a higher level than Congress funded, enactment of legislation to extend to 1992 and possibly increase energy tax credits for qualifying solar energy properties, and an increased utility generating requirement resulting from a growing economy.

I add to these assumptions the negative factors of prior year congressional action on TEFRA of 1982 and the rescinding of the 1985 and 1986 writeoff schedule pursuant to the accelerated cost recovery system, and the enactment of the basis adjustment provision which greatly diluted the value of the energy tax credit.

These various events have created a less than favorable climate in which industry can be expected to meet financial hurdles to move solar thermal technologies.

The recommendations put forward in this statement recognize these changes and the fact that industry still requires a DOE partnership.

We need near-term large-scale component development as well as the long-term research. Continuing Government support in the form of tax incentives or loan guarantees and budget outlays are needed to provide a stimulus to the private sector investment. We can see the dividend for these technologies beginning to pay off. We know of no other renewable energy program that has met with more technical success given the magnitude of technical complexity.

The Government/industry partnership is working. First, Solar I, the 10 megawatt powerplant, is generating valuable operating data since April 1982. As of mid-February 1984, 8,800,000 kilowatt hours of energy have been produced.

Second, a team was selected and performed detailed design for a 30 megawatt power project with Government cost sharing.

Third, the small-scale molten solid electric experiment is operating at the test facility in Albuquerque.

Fourth, the Arco Solar 1 megawatt enhanced oil recovery system is operating in a California oil field and meeting performance goals.

Fifth, Arizona Public Service is continuing the effort to develop the 60 megawatt Sequoia repowering project.

Finally, sixth, Southern California Edison has joined with industry to further develop the project structure for Solar 100, the first commercial-sized powerplant with the rated capacity of 100 megawatts electric.

Finally, Mr. Chairman, let me briefly summarize the specific budget recommendations for fiscal year 1985 which are supported by the preceding and attached discussion.

The attached budget recommendation totals $54.7 million. This level is over $17 million more than the administration request for fiscal year 1985. This level includes $14 million for research, $27 million for central receiver R&D, over $12 million for parabolic dishes, and $1.7 million for planning and project support.

This increase along with $15 million per year continuing into fiscal year 1986 and fiscal year 1987 for support of one or two large-scale experiments provides for near-term emphasis on the needed research and development to bring along central receiver technologies into the final stages of commercial market development.

Also Government-supported solar fossil hybrid experiments can provide an attractive option for technology transfer in the near term. As described, funding for operation of the Government's test facilities, Solar I subsystems or component development is included. A more detailed line item description is included in the statement.

We think that this budget recommendation at $54.7 million outlines a reasonably balanced structure between research and development for fiscal year 1985 which is built upon the administration's program and provides additional emphasis on near-term sybsystem component development and support for large-scale experiments.

Furthermore, it recognizes the need to hold down the Federal budget level with the minimum of out-year carry-over and yet maintains the momentum of the viable technology with the substantial investment that the Government has already made.

We respectfully request the subcommittee's continuing support of solar thermal technology and the need for Government/industry partnership.

Thank you for the opportunity to submit this testimony.

[The prepared statement of Mr. Hildebrandt follows:]

STATEMENT OF FRANK DUQUETTE/ALVIN HILDEBRANDT, SOLAR THERMAL DIVISION, SOLAR ENERGY INDUSTRIES ASSOCIATION

"No single prescription exists for a solution to the energy problem. Energy conservation is not enough. Petroleum is not enough. Coal is not enough. Nuclear energy is not enough. Solar energy and geothermal energy are not enough. New ideas and developments will not be enough by themselves. Only the proper combination of all of these will suffice."

-- Energy From Heaven and Earth, 1979

1.0 FOREWORD

This presentation describes solar thermal systems that can provide significant displacement of our fossil fuel resources by supporting industrial energy needs. The technology offers potential for not only providing an environmentally clean energy source, but also stimulating industrial growth with the associated jobs, tax revenue and other benefits.

The discussion outlines past accomplishments of the government/industry partnership in developing this technology and the need for a moderate level of continuing government support to achieve timely transfer to the private sector for a multiplicity of applications.

Technology readiness and market acceptance, financial and technical barriers, potential oil displacement, other government financial support options and related benefits are outlined.

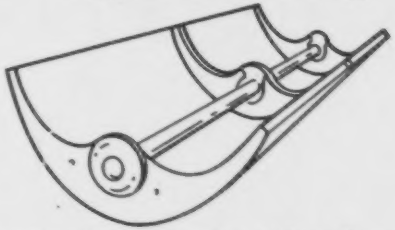
The industry recommended FY '85 DOE R&D budget for solar thermal technology is $54.7 million. In relation to the Energy Department's FY '85 requested total budget of 12.815 billion dollars, $54.7 million represents a rather moderate 0.4% share.

We believe this funding level provides a reasonably balanced effort for FY '85 which builds upon the Administration's program and provides additional emphasis on nearer term subsystem/component development and support for large scale experiments. Furthermore, it recognizes the need to reduce federal spending levels, with a minimum of out year carry-over and yet maintains the momentum of a viable technology in which a substantial investment by the Government has already been made.

SOLAR THERMAL SYSTEMS CAN CONTRIBUTE SIGNIFICANTLY TO US ENERGY REQUIREMENTS

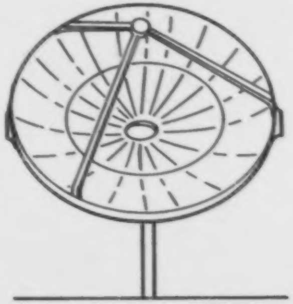
VGM297

Single-Axis Tracking



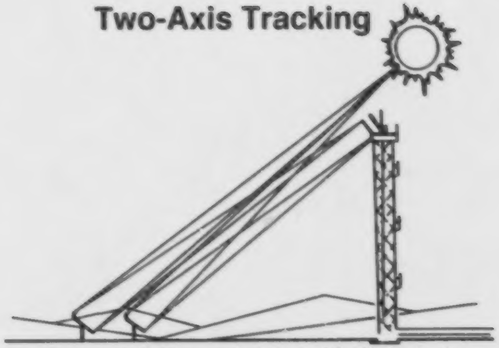
Parabolic Troughs, Line Focus

Two-Axis Tracking



Parabolic Dishes, Point Focus

Two-Axis Tracking



Central Receivers, Heliostats

2.0 INTRODUCTION

Mr. Chairman, members of the Committee, the Solar Thermal Division of the Solar Energy Industries Association appreciates this opportunity to testify on the FY 1985 budget pertaining to the solar thermal technologies. Once again, significant accomplishments and positive outlooks for the future have marked this past year as a result of an ongoing government/industry partnership. As an industry association, we can now envision, with the recommended budget levels, market acceptance of the technology with development risks regarded as manageable by the private sector in the near term.

With regard to a related issue, we appreciate and support the Chairman's leadership in proposing an extension beyond 1985 of the Federal Energy Tax Credits which represent an appropriate role for the government to take to help create this emerging high technology industry.

2.1 SOLAR THERMAL DIVISION

The Solar Thermal Division, a division of the Solar Energy Industries Association, is an industrial organization fulfilling a vital role in the commercialization of solar thermal systems. Division member companies have consistently been at the forefront in advancing solar thermal technology through commitment of their own resources in close cooperation with federally supported research and development programs in solar energy. Ranging in size from large, multinational, energy and aerospace corporations to small, innovative firms, our members are world leaders in solar thermal technology. This leadership is based on experience gained through the 1970's, beginning with the early efforts of the National Science Foundation Solar Program. Nearly 10 years of accelerated effort have led to the development of advanced system designs that have exceeded almost all performance expectations. The transition from early engineering and test prototypes to full-scale operating systems for industrial and utility users is nearing reality.

This industry group, although not in agreement with the current administration's policies on renewable energy development, has responded to the policy shifts in the government's energy research and development program by implementing an orderly transition from system level engineering to a more research and applied development program. It should be kept in mind, however, the importance at this stage in this technology's development of the need to preserve the vast federal and corporate investment represented by existing test facilities. It is also important to continue and complete the component development program and last-step engineering phases that will help propel industry over the last major research and development hurdle that remains.

I know of no other renewable energy program that has met with more technical success, given the magnitude of the technical complexity. The government/industry partnership is working, and the end of direct support is within sight. Three years of additional direct support of the major technologies at level funding, relative to FY 1985, would appear to be adequate to complete the transition.

I firmly believe that the balance of this testimony will establish that there are significant technical dividends that have resulted from this committee's support of solar thermal technologies. I also believe that the work accomplished to date and the prospects for the future justify our FY 1985 budget request.

2.2 TECHNOLOGY SUMMARY

The major thrust of the government/industry partnership in the solar thermal program is to establish a capability in the private sector to deliver technically proven, cost-effective thermal systems for converting sunlight to low-, medium-, and high-temperature heat. Capabilities in these temperatures permit a range of potential applications which is unusually large and diverse. The heat can be used directly in industrial processes, be converted to electricity, or be applied directly to endothermic chemical reactions to produce fuels.

The technical feasibility of concentrating solar thermal systems has been established by a combination of government and industry supported efforts during the past decade. The federal/industry investment alone has reached a level of over 500 million dollars. The resulting cost of solar thermal energy hardware has dropped significantly in the years since the inception of the program.

The commercial viability of solar thermal energy systems is tied to full scale system level product readiness and to its cost/value relationship with other energy supply options. Further reductons in systems cost will be necessary in order for solar thermal energy systems to compete strongly with fossil fuel based systems and other renewable energy options. Furthermore, operation of commercial scale systems must be conducted for complete technology transfer to the private sector and to gain user industry acceptance.

Cost goals for economic competitiveness and user acceptance have been established for electricity generation and heat production as shown below for the year 1990. Cost goals on the order of 25-50 percent lower than 1990 levels will be achievable by 2010.

Application	1990 Goal (1983 $)
Electricity	6-12¢/kWh
Heat	7-12$/MBtu

The following design basic concepts are continuing development under this program. These design concepts are:

- Central Receiver Systems
- Parabolic Trough Systems
- Parabolic Dish Systems

Hemispherical bowl and solar pond technology is either in the private sector or has been phased out of the program.

The table on the following page shows the market areas that offer the greatest market potential for each design concept.

Parabolic dish prototype hardware R&D&D is currently being successfully conducted in the field. Recent experience with test facilities and operating system experiments has demonstrated levels of equipment reliability and durability for heliostat systems and parabolic troughs which are consistent with market demands for specific applications. With the availability of government support for large scale system and subsystem experiments, mass production of collector prototypes already developed will reduce near term system costs to acceptable levels and promote the production levels needed to achieve stated cost goals in the 1990-2000 period.

2.3 MARKET ASSESSMENT

2.3.1 CENTRAL RECEIVER

In view of the administration's policy of supporting only high-risk long term research, the solar industry feels the urgent need to review the current state of development and commercial readiness of this technology. In particular, we want to highlight the importance of the central receiver technology and the need for government support of

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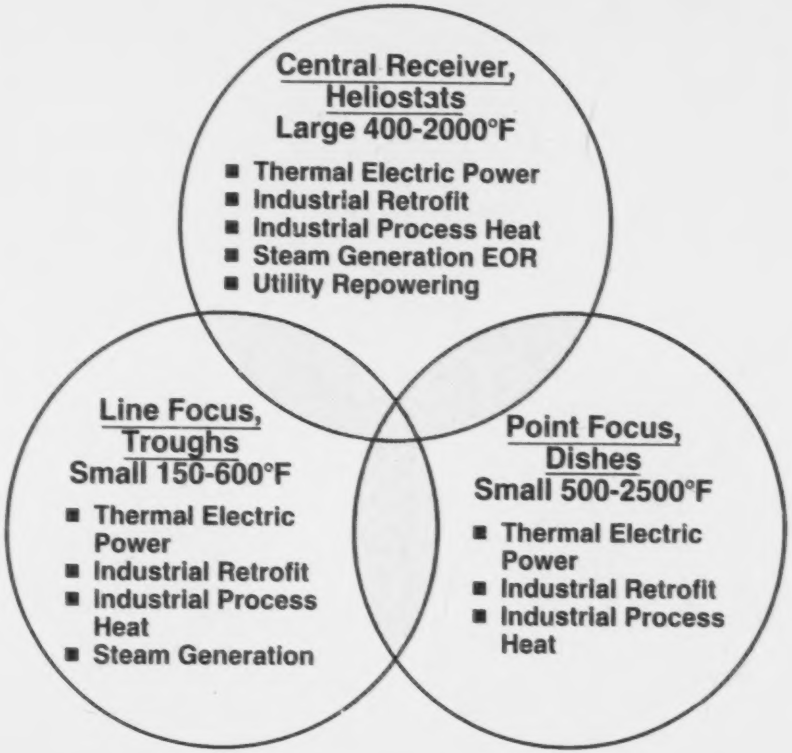
PRIMARY SOLAR THERMAL, TECHNOLOGIES AND APPLICATIONS



Central Receiver,
Heliostats
Large 400-2000°F

- Thermal Electric Power
- Industrial Retrofit
- Industrial Process Heat
- Steam Generation EOR
- Utility Repowering

Line Focus,
Troughs
Small 150-600°F

- Thermal Electric Power
- Industrial Retrofit
- Industrial Process Heat
- Steam Generation

Point Focus,
Dishes
Small 500-2500°F

- Thermal Electric Power
- Industrial Retrofit
- Industrial Process Heat

MARKETS ADDRESSED BY STES	MARKET SECTORS	SPECIFIC APPLICATIONS	APPLICABLE COLLECTOR/ CONCENTRATOR TECHNOLOGY	APPLICABLE STES PROJECTS/ACTIVITIES
ELECTRIC POWER	Large Utilities	• Repowering Existing Fossil-Fueled Plants • New Capacity Additions • Base Load • Base Load (Site Specific)	} Central Receivers Solar Ponds	• Barstow 10MWe Pilot Plant • Utility Repowering – Carissa Plains – Saguaro • Solar 100 • Salton Sea
	Small Community Systems	• Remote, Island Powerplants • Military, MX-RES • Municipals, Rural Coops	} Parabolic Dishes } Bowls	• Small Community (EE-1) • Military Module (EE-2A)
INDUSTRIAL	Process Heat	• Large, 200-2000°+F • Small, 200-2000°+F • Small, 200-600°F • Low Temp. < 200°F, (Site Specific)	Central Receivers Parabolic Dishes Parabolic Troughs Solar Ponds	• Industrial Retrofit • Industrial Applications Experiments (EE-3) • SCSE
	Cogeneration/ Total Energy	• Small Industrial, 200-1000°F	Parabolic Dishes	• Shenandoah • Rancho Mirage
		• Large Industrial	Central Receivers	• DOE Industrial Retrofit Adv. Concepts
		• Small Industrial, Commercial, 200-600°F	Parabolic Troughs	• Mid-Temperature Solar Systems Test Facility (MSSTF)
	Production of Fuels and Chemicals	• Hydrogen Fuel TBD	Central Receivers Parabolic Dishes	• Explorator and Supporting Research (Seri/Sandia)

TABLE 1

large scale experiments to achieve transfer to the private sector of its many applications and potential to provide environmentally clean, affordable utility power in the late 1980's, 1990's and beyond.

The solar thermal central receiver program, a program with 10 years momentum, is nearing the point of being passed from government to the private sector. This technology has not yet reached the stage in its development where it can be continued and completed by private capital alone. However, it is capable of being economically competitive and can help to stabilize and lower the cost of electricity for the ratepayer in the next decade. Utilities and power companies consider this potentially an important source of power generation for future generating capacity, but cannot complete development without shared federal assistance.

The research and development and proof of concept experiments have proven STCR to be technologically sound and environmentally safe. The STCR technology is modular and can be installed in four to seven years, as opposed to the eight to 15 years required for fossil fuel and nuclear generating facilities. And, more importantly, the technology provides for national and regional energy security by displacing foreign oil supplies. For example, a 100 MWe central receiver solar electric plant (capital cost approximately $400 million) would displace approximately 800 thousand barrels of oil per year. Industry studies indicate a potential market for 50-80 solar electric plants of this type in the southwestern U.S. through the year 2010, so that a total displacement of more than 40 million barrels of oil per year is realistically achievable. Additional oil displacement could be achieved for solar industrial process heat applications, including steam for enhanced oil recovery.

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SOLAR CENTRAL RECEIVER COMMERCIAL MARKET

Sizeable Market Exists — 8.0 GW = 80 100 MW Plants

Capacity (GW)

EPRI Regional Areas	Existing Capacity	Projected Growth in Markets Solar Thermal Only			
		1984-91	1992-96	1997-2002	Growth Totals
Total ERCOT (Texas)	(31)				
Texas Utility Company	17	5.4	4.9	5.9	16.2
		0	0.8	1.5	2.3
Total WSCC (W-Tx, W-NM, Co, Wo, W-Mt, Id, Ut, Az, Ne, Ca, Or, Wa)	(43+)				
CA (SDG&E, PG&E, SCE)	35	4.6	4.0	6.0	14.6
		0.2	1.4	3.0	4.6
Others (APS, EPE, PNM, SRP, SPP)	8	1.5	1.0	1.4	3.9
		0	0.4	0.7	1.1
Totals	60	11.5	9.9	13.3	34.7
		0.2	2.6	5.2	8.0

TABLE #2
-6.5-

2.3.2 UTILITY GENERATION

Generating capacity for the 1990 time frame and beyond is presently a part of utility planning activities. Several utilities are planning for central receiver power plants in their power generation forecasts for the following reasons:

> Solar can be used for short-term intermediate capacity operation previously served by oil and gas, such as the repowering of existing oil and gas fired units (post 1986 operations) and standalone plants.
>
> Smaller capacity additions on the order of 50-100 megawatts electric (MWe) are particularly suited to utility needs and avoid the problems of long licensing and permitting requirements and construction times associated with other types of projects, as well as significant reductions in capital funding requirements and the cost of that money.
>
> Integration and operation of central receiver power plants fit well into utility generation systems. The central receiver technology adapts reasonably well with available thermal electric generating technology, with which utilities are familiar and have extensive operating experience.
>
> These units, once the cost of construction is in place, offer protection against escalating fuel and transportation costs--issues of great importance to stabilizing utility rates for the customers of electric utilities.
>
> STCR operation is virtually free of air and water pollution and solid waste disposal problems and costs.

3.0 SIGNIFICANT ACCOMPLISHMENTS

3.1 CENTRAL RECEIVER

Significant progress continues for the development of solar central receivers technology and applications:

1) Solar One--the 10 MWe pilot plant for generating valuable performance and operating data since turbine roll in April 1982.

2) The ARCO Solar 1MW EOR System is consistently providing solar generated steam for heavy oil recovery near Taft, California.

3) An industry team was selected and is performing detailed design for a 30 MW grid repowering project with government cost sharing.

4) Southern California Edison has joined with industry to further develop project structure for Solar 100, the first commercial sized central receiver power plant at 100 MWe.

3.1.1 Solar One

The 10 MW solar thermal central receiver pilot plant became operational in April 1982 and is currently the world's largest electric generating station powered by solar energy.

This plant was the result of a joint effort between Southern California Edison, the Los Angeles Department of Water and Power, the California Energy Commission, and the U.S. Department of Energy. The plant has operated at 10.4 MW net electrical output, which is slightly in excess of its rated output, and has produced over 6,833,400 kWh of net energy through mid February 1984. Power output of 7.3 MWe from storage has been achieved, an accomplishment which satisfies another design milestone for the plant. Heliostat availability has been demonstrated to a 99% level with nominal maintenance. Fatigue cracks were detected in the high temperature solar boiler tubes during the latter part of 1983. Receiver structural modifications to substantially reduce thermal stresses and increase tubing lifetime were completed in February 1984. Studies are continuing to define means to further prolong receiver lifetime by revising heliostat aiming strategies to reduce receiver peak temperatures and thermal gradients.

The dual media thermal storage system has demonstrated that stable thermoclines can be maintained in an operational environment and plant automation continues on schedule for demonstrating a clear day operating scenario.

Valuable design verification data is being obtained from the naarly completed two-year test and evaluation program. The power production phase to allow hands-on utility operation will be initiated later this year and continue for one to three years.

3.1.2 Repowering

Four preliminary design studies for solar central receiver power plants have been completed. These preliminary design contracts involved significant cost sharing between the industry participants and the DOE. Three of these plants are for utility power generation operations with sizes from 30 to 66 MWe. They studied the use of liquid sodium, molten salt, and water as the heat transport fluids. The fourth design was a 31.8 MWe cogeneration project in Hawaii using water for heat transport.

DOE selection of a cost-shared detailed design effort was made utilizing the PG&E/Rockwell 30 MW sodium cooled receiver grid repowering design. This selection was based on an accelerated schedule in order to attempt to be on line in mid 1986.

The Arizona Public Service 66 MWe molten salt system design for repowering the Saguro plant has proposed an R&D approach for continuing development of the project.

It should be noted that the above projects, including the Solar 100 initiative, are struggling to maintain favorable economics in the face of current lower fossil fuel prices and the potential loss of energy investment tax credits after 1985.

3.1.3 Solar 100

Southern California Edison has been a leading utility in expressing interest in renewable energy sources, with plans for 2190 MW by the early 1990's. Of this, 300 MW electric has been designated to come from solar energy. SCE has given considerable incentive to industry through its Solar 100 solicitation.

Four companies responded to the Edison request to participate in a conceptual engineering study for a 100 MWe commercial plant. Late last year, Edison selected the McDonnell Douglas design approach utilizing a two module molten salt system. This user/designer team is currently developing a project structure which is targeted to be operational in the 1988-1989 time period.

3.2 PARABOLIC DISH

3.2.1 The Parabolic Dish Stirling Cooperative Agreement completed its design and fabrication phases. It is presently operating daily at Rancho Mirage, California and has achieved electrical outputs of 22.8 KW for a conversion efficiency of sunlight to electricity of 28.9%.

3.2.2 The Organic Rankine engine successfully completed 100 hours of simulated on-sun operations in the laboratory. The sub atmospheric brayton module achieved system checkout and integration, and the instrumentation and controls were developed.

3.2.3 U.S./Sweden industrial firms have consummated a cooperative agreement for the development of commercial scale dish stirling concentrators (25KWe).

3.3 PARABOLIC TROUGH

3.3.1 An American Solar King 60,000 ft^2 commercial IPH line focus system is in operation for Gould Corporation.

3.3.2 Heavy effort to develop private sector financing for commercial projects is continuing.

3.3.3 MISR systems in operation at Sandia-Albuquerque and SERI are providing valuable test data and operating experience.

3.3.4 Operating data from 12 IPH projects is being made available to industry.

4.0 STATE OF THE INDUSTRY

Growth in electricity demand has outpaced U.S. GNP growth over the past twenty years, and this trend is expected to continue in the decade ahead. A recent study of the U.S. electric industry by the DOE Office of Policy and Planning and Analysis predicts that electricity usage will account for an increasing share of total U.S. energy usage. Furthermore, because of restraints on utility investments by regulatory agencies and the problems experienced by the nuclear industry, electric generating plant additions planned and under construction may be inadequate to meet the projected need by 1990. Considering the lead times required for major plant construction, an even more serious shortfall (as much as 60GW) could result if the economy expanded at a 1% higher than projected annual rate, and if some of the plants now in construction are not completed or are cancelled.

With a moderate amount of continuing Government support, solar thermal electric systems can provide a contribution to meeting the need for generating capacity during the latter half of the decade due to their shorter construction lead times, and can provide an attractive option to other generating alternatives, such as combustion turbines.

A just released Frost and Sullivan market study estimates that solar thermal electric systems will contribute 10GW to the world power grid by 2010. Solar related equipment and service sales are also seen rising from the 1982 level of $488 million to $6 billion by 2010. To put this growth forecast in perspective, market penetration for this environmentally clean, renewable energy option moves from 20 MWe in 1982 to 10,000 MWe by the first decade of the next century.

It should be noted, however, that with reduced federal support for solar, along with a strong dollar that drives up the cost of U.S.-made goods abroad, the study sees Japan moving into the market.

"Very large individual plants are planned in both the USSR and India," and the study predicts that "as Japan and the Far East begin to recognize the importance of solar electric generation, we will see dramatic changes" in their level of investment.

A recent market penetration study conducted by one of our industrial member firms forecasts a potential of as many as 80 100 MWe solar central receiver plants fulfilling utility power intermediate load needs in the southwestern U.S. by 2002. Refer to table in Figure 1.

4.1 BARRIERS TO COMMERCIALIZATION

A number of issues must be resolved to clear the hurdle for commercial scale hardware project experiments leading to market acceptance:

> Financing: Project financing is not available for large new technology plants. Further, the high initial cost compared to revenues available at current electrical energy price precludes returns on investment required in the marketplace. Private sector investors are concerned about the availability of the 15% investment tax credit extension to 1992, and possible enhancement.
>
> Risks: Neither industry, utilities nor ratepayers are able to assume a disproportionate amount of the financial risk for first large scale experiments. Government support in the form of loan guarantee or energy price guarantee and technology budget outlay is required.
>
> Regulation: Federal law exempts third parties from utility regulation for solar plants less than 30 MW. Larger plants are subject to utility regulation unless exemptions can be obtained for accounting, tax implications, and other burdens of utility regulation which are difficult for third party investors.

Technical: Some residual component and subsystem technology verification remains to be accomplished by the government's research and development program.

Energy Cost: Electrical energy prices today are depressed by current low oil and natural gas prices. This creates an imbalance between plant value and cost at this time.

4.2 SUMMARY OF SEIA/INDUSTRY STUDIES AND REPORTS

During 1983, the SEIA completed several studies on the current status of the solar thermal industry. They are:

An Assessment of the Impact on the Solar Central Receiver Industry if Federal Energy Investment Tax Credits Are Not Extended in 1983

The Availability of Industrial Capacity to Produce Solar Thermal Energy Systems

Avoided Cost Standards and Practices Under the Public Utility Regulatory Policies Act

Assessment of Failure to Pass a Tax Credit Extension

Review of the status of central receiver technology revealed the initial dependence of commercialization this technology has on extensions of the business energy investment credit. In 1983, four preliminary designs for repowering plants were completed, and a team selected to proceed with a final design of a 30 MW plant. Two other initiatives continue to be active, a 100 MW plant proposed to Southern California Edison Company, and a 60 MW plant proposed by the Arizona Public Service Company.

Readying this technology for commercial introduction requires successful operation of a plant larger than the Solar One experiment. Change in the basic strategy of the federal R&D program has placed reliance on the private sector for funding construction and operation of such a plant. To date, no third-party group has been assembled to maintain a CR project. With expiration of the credits now 22 months hence, construction lead times of three to four years, and the need to place key component orders in mid-1984 for any plant to begin construction in the next 12 months, it is completely unlikely any project will go forward without extension of the tax credits before summer 1984. Should Congress fail to extend the credits, the SEIA assessment indicated the following could occur:

> Failure to pass the credits extension legislation in 1983 signals a major defeat for the several projects still trying to arrange finance and get construction started.
>
> The investment community loses interest in central receiver projects because planning cannot be initiated or sustained with the high degree of uncertainty about financing.
>
> The solar companies retrench, halt their own market development expenditure, but continue to bid R&D contracts as they become available. The companies begin to pay more attention to longer-range applications, such as fuels and chemicals. Some may consider trying to develop small industrial process heat systems.
>
> Near-term commercialization ceases because the interested utility companies abandon central receiver technology. They see industry halting commercialization activity, and because their planning horizon has already stretched out to 1995, they give it up.

The abandonment of near-term commercialization by industry reduces industry pressure on Congress and the Department of Energy to maintain the present levels of appropriations for solar thermal R&D. Nonetheless, industry may besiege Congress with a plan for a fully government-supported commercial demonstration plant, contending higher petroleum prices will so raise avoided costs in the 1990's that utilities will renew their interest in central receiver technology.

Base technology support for Solar One, the Molten Salt Electric Experiment and Repowering is eliminated from the R&D program, and the federal budget is reduced accordingly.

This assessment was prepared with the cooperation of several companies involved in central receiver technology. It does not represent a formal Solar Thermal Energy Division statement.

Industrial Capacity to Produce Solar Thermal Energy Systems

SEIA reviewed forecasts of power plant construction through the 1980's and the historical accuracy of such forecasts from 1978 to 1982. Capacity utilization of equipment manufacturers for fossil and nuclear power plants and of aerospace companies was analyzed. Because they account for approximately forty percent of central receiver plant capital cost, industry approaches to mass producing heliostats were also examined.

This survey of conditions in the power market and industry capable of delivering central receiver technology revealed two important findings. First, projections of utility plant capacity additions have usually overstated actual construction, and, if trends in the recent past continue, very little new business for the power equipment industry will be forthcoming this decade. Consequently, the power generation equipment industry is suffering a severe underutilization of its capacity. It is capable, with a minimum of new investment, of meeting any expected demand in the 1980's for solar central receiver plants. If conventional plant manufacturers decommission capacity, but a market develops in five to seven years based on replacement of aging power plants, solar thermal plant constructors may find they have to compete for capacity to produce their systems.

The second finding concerns production of heliostats. A survey of potential suppliers of heliostats revealed two paths to creation of mass production capability. Aerospace firms involved, despite their own excess capacity, expect to invest in new facilities for large volume production. Another major participant has identified a second approach, however, which would minimize investment in production facilities and rely on existing capacity that is producing on a regular basis most of the parts needed to build a heliostat. It is unclear which of these paths will be the foundation of the commercial introduction of central receiver technology.

Avoided Cost Standard and Practices Under the Public Utility Regulatory Policies Act

The Solar Energy Industries Association examined the relevance of PURPA legislation, specifically Sections 210 and 201, to solar thermal project developers. The study provides an understanding of the avoided cost standard used by electric utilities to calculate the price paid to small power producers, and of the interconnection and qualifying requirements for such producers. SEIA also surveyed important actions state utility commissions and utilities have taken and the limited experience to date of solar thermal projects proposed under PURPA guidelines.

The court challenges to Federal Energy Regulatory Commission rules implementing PURPA provisions favoring independent power producers have been decided in FERC's favor. Most states have proceeded to adopt the FERC rule and established rates which meet the definition of full avoided costs. Compliance with PURPA has therefore been almost universal; but, in practice, the result has been a great variety of rate-setting methods. Thus, after four years, avoided cost is still an evolving issue.

Opportunities exist to improve the avoided cost picture for solar thermal projects, and would concentrate on:

Identification of the most favorable marginal plants

Avoiding use of historical averages

Inclusion of O&M and line loss factors in avoided cost calculations

Another area of dispute concerns capacity credits, which can amount to as much as 10 percent of full avoided costs. Capacity credits have so far proven difficult to calculate and are controversial. One problem is in predicting accurately the future generation mix of a utility's baseload facilities and its true avoided capacity costs. Few widely accepted methods exist, and room for interpretation is great.

Support for capacity credits for solar thermal systems should be readily forthcoming given performance to date of the 10 megawatt pilot plant (Solar One) at Barstow, California.

Examination of issues surrounding establishment of power purchase rates for independent power producers revealed that alternative approaches may be required. A fundamental question unresolved is who would help pay for development of new power generation technologies.

Utilities have petitioned for rates higher than avoided costs, and others contend that avoided cost formulae do not reflect many hidden costs associated with proceeding with conventional energy technology. Solar industry representatives have suggested that the energy cost of new generation projects, typically twice any avoided cost figure calculated currently, be defined as "avoided cost."

In summary, Federal Energy Regulatory Commission rules of PURPA avoided cost stipulations have been upheld, and PURPA Sections 201 and 210 are working to increase independent power production. Solar thermal technology projects are few, and adjustments to current procedures, calculation methodologies, and rules interpretations may be necessary for large-scale solar thermal projects to make headway under PURPA provisions. It is clear that any solar thermal initiatives will be considered on a case-by-case basis by the regulators for the foreseeable future.

5.0 PROPOSED FY 1985 BUDGET

The Administration's FY 1985 budget request for the Solar Thermal Technologies discussed today is $37.5 million. This figure represents only something over one-half of our industry request.

The STEA considers the Administration request inadequate in light of the significant accomplishments and the remaining tasks. Included herein is a comprehensive alternative budget that totals $54.7 million. In the next section, we have spelled out our rationale for each line item and we feel that our submission represents a realistic and balanced approach to the development of solar thermal energy. The difference in the two budget requests represents the difference between having a viable, near term, job-producing industry, or a program resulting in longer delays and the potential of loss of significant industry involvement and support.

FINAL
2/24/84

SEIA SOLAR THERMAL DIVISION
FY 85 TECHNOLOGY BUDGET RECOMMENDATIONS

A. RESEARCH				13.9
1. EXPLORATORY				
a) Materials		3.3		
b) Innovative Concepts (PRDA - New & Follow-on)		1.0		
c) University Thermal Research		1.7		
d) Photo/Thermal Chemical		.7		
2. SUPPORTING				
a) Innovative Collectors, Concentrators and Refractive Devices		2.0		
b) Parabolic Trough Materials		0.5		
c) Parabolic Dish Materials, Controls & Thermal Storage		1.8		
d) Fuels & Chemicals (Hi-Temp Receiver/Reactor 1500°F-2500°F)		2.9		
B. CENTRAL RECEIVER RESEARCH & DEVELOPMENT				26.7
1. SUBSYSTEM/COMPONENT DEVELOPMENT			8.9	
a) CRTF Operations		1.4		
b) Subsystem Component Development -2nd Generation Receiver -Steam Generator, Storage		6.5		
c) Automated, Unattended Control System		1.0		
2. EXPERIMENTS			17.8	
a) Solar I				
-O&M		3.6		
-Performance Analysis & Test		1.0		
b) MSEE Operations & Test		2.4		
c) Large Scale Experiments -Direct support of one or more industrial team projects		10.3		
d) Small, Remote System Concepts		0.5		
C. DISTRIBUTED COLLECTOR TECHNOLOGY DEVELOPMENT				12.4
1. PARABOLIC DISH			11.9	
a) Test Facilities		1.5		
b) Thermal Transport		1.7		
c) Dish Electric		4.2		
-Brayton	2.5			
-Free Piston Stirling	1.7			
d) Adv. Concentrator		3.0		
e) Small Community System Experiment		1.0		
f) Capital Equipment		0.5		
2. PARABOLIC TROUGH - Operation, Refurbishment & Performance Data			0.5	
D. PLANNING AND PROGRAM SUPPORT				1.7
TOTAL				54.7

5.0 PROPOSED FY 85 BUDGET

SEIA SOLAR THERMAL DIVISION
FY 85 TECHNOLOGY BUDGET RECOMMENDATIONS

A. RESEARCH

1. EXPLORATORY

a) Materials. An amount of $3.3 mil is recommended for work in the following areas: Reflective surfaces (glass, plastic, acrylic coatings, etc.); anti-reflective, selective and absorptive coatings; seals; improved glass (thin, strength); high temperature, flexible hoses; structural materials (weight, price, strength, cycle life); ceramics; transparent windows; cavity insulation and shielding at operating temperatures; insulation for high-flux systems (1.5 MW/m^2 to 2.0 MW/m^2); corrosion-resistant properties of low-cost materials for nitrate salts; and measurements of physical properties of nitrate salts.

b) Innovative Concepts (PRDA - New and Follow-on)

An amount of $0.5 mil is recommended for solicited innovative research. It is recommended that evaluation of the PRDA responses be carried out or monitored by a peer review committee incorporating a majority of university researchers. This will both assure the high quality of the research undertaken and assure that the research is outside the area of immediate problem solving. It is also recommended that $0.5 mil be made available for two to three follow-on experiments (Phase II) selected from the present innovative research contracts.

c) University Thermal Research

The expansion of the solar thermal technology base for cost effective approaches to future commercial market applications requires continuity of research direction and funding. In the view of industry, the research program should be addressing the needs related to performance improvement, cost reduction of critical subsystems (collectors, receivers, etc.) and expansion into new applications such as fuels and chemicals. The research should emphasize the removal of technical barriers prior to engineering development by industry.

Research work carried out by U.S. universities continues to be useful in identifying promising concepts and processes in solar thermal technology and transitioning technology to private industry. It is recommended to continue funding for the ongoing Solar Thermal Advanced Research Activity Center (STARC) at the University of Houston (UH) at $0.7 mil and at GIT at $1.0 mil. The GIT funding level recognizes the presence of the Advanced Components Test Facility (ACTF) at GIT and includes $0.25 mil to maintain it in an operational status.

d) Photo/Thermal Chemical

$0.7 mil is recommended for basic research of photochemical effects of high flux and high temperatures for various atmospheres. This work is needed to better understand degradation of receiver surface materials, both for external and direct flux particle receivers.

2. SUPPORTING

a) Innovative Collectors, Concentrators & Refractive Devices

Reflector materials development for low cost, lightweight concentrators. The program includes research and small scale experiments to develop silvered polymeric reflectors having 92% reflectance, 15 year life, and resistance to ultraviolet and environmental attack. The program will also include research to establish the feasibility of polymer materials for structural membranes with an emphasis on creep fatigue, durability under wind and hail impact, ease of handling and attachment, optical quality, stability and weatherability ($1,950,000). Refractive devices, i.e., linear fresnel lens concentrator, for IPH applications up to 500°F should be included.

b) Parabolic Trough Materials

A funding level of $0.5 mil is provided to support continuing generic R&D for components and materials which will provide higher performance, lower capital costs and longer lifetime for trough hardware. A priority need is for lower cost, 20-year life, relfective services with greater than 96% reflectivity, and high production volume cost of $1.50/ft^2 or better. Other important areas include high temperature heat transfer fluids; higher emmissivity, long life, absorptive coatings for receivers; long life, stable evacuated tube receivers.

c) Parabolic Dish Materials, Controls and Thermal Storage

The materials and component research program shall support the parabolic dish technology by providing $1.8 mil towards heat pipe/thermal storage receivers, application of fiber optics for dish controls and reflective surface material development for compound curvature applications. Large fresnel lens point focus acrylic material coupled with rigid supporting structure should be investigated.

d) Fuels and Chemicals

Thermo chemical and high temperature receiver/reactor (1500°F-2500°F) concepts definition and development. Although the solar thermal industry recommends that R&D in the area of the application of solar thermal processes to the production of fuels and chemicals be continued, we do not feel that it should have a high priority since it cannot have a near-term impact on stabilization of energy prices or on energy independence. We do feel, however, that a $2.9 mil effort is justified, provided it is expended on research of processes and systems that can potentially apply to a broad range of current industrial processes and with increased chemical industry participation. Direct flux particle receivers need basic/exploratory research as well as development. Even though, for example, a long-term goal of producing hydrogen by means of thermochemical processes appears to be promising, that goal should be reached via analyses, research, and development which can be of use to the U.S. industry in the near term. The industry feels that funding for research and development in the field of fuels and chemicals should be kept at a relatively low level until the nearer-term technology development applying to the parabolic dish and central receivers is at a stage at which it can and will be picked up by the private sector for commercialization. Out-year budgets for fuels and chemicals are, therefore, recommended for increases consistent with the potential impact they can have on the longer term energy supply for the U.S.

B. CENTRAL RECEIVER RESEARCH & DEVELOPMENT

1. SUBSYSTEM/COMPONENT DEVELOPMENT

a) CRTF Operations

The CRTF continues to be a valuable research tool for central receiver development. The ability to transfer the solar central receiver technology to the private sector at any time will depend to some extent on the degree to which the technical feasibility of the process or the performance of a component has been verified at a real solar source. In addition, private industry anticipates a need to have facilities available (much like those available for high energy physics or nuclear research) at which testing can be conducted on hardware designed and fabricated by private industry. Any given private organization could not afford or justify keeping a facility active on the basis of the infrequent times at which its own needs must be met. Industry feels, therefore, that this need should be logically and properly met by federal involvement. A budget of $1.4 mil is recommended for FY 1985, and similar budgets are required for out-years for this facility.

b) Subsystem/Component Development

One of the major barriers that impedes the ability of industry to pick up the central receiver technology is the high cost and high risk associated with the development of certain key central receiver components. Principally, these components are the receiver, the steam generator, and storage. In order to reduce the perceived risk of these components to the point at which the private sector can pick them up and complete the development for commercialization, the industry recommends a base technology development effort which includes the receiver as well as the other two key components, for both molten salt and sodium systems.

Recommendations for molten salt work are as follows:

Extended Receiver Test, CRTF: $0.5 mil. Twelve month extended lifetime and performance testing of Category B 5 MW_t model molten salt receiver.

Continued development of operating strategies including overnight drain-down vs warm stand-by, transient responses, and reduction of thermal cycling effects. Extended testing and experience with heat tracing and salt line instrumentation.

Extended Pump and Valve Test, CRTF: $0.8 mil. Twelve month extended full-scale molten salt pump and valve testing for performance and reliability. Data to be collected under both hot (1050^{O}F) and cold (530^{O}F) conditions. If only the hot (or cold) loop tests are conducted under Category B, then the corresponding cold (or hot) loop tests must be conducted here. Extended testing and experience with heat tracing and salt line instrumentation.

Storage Tank Thermal Cycling: $1.1 mil. New experiments with molten salt storage tanks to test a scale version of the preferred full-scale design for resistance to thermal cycling and for leak detection methods.

Physical Property Test, Cover Gas and Metals Corrosion: $0.3 mil. Extended monitoring of molten salt properties, including the addition of additives for lowering the melting point and raising the operating temperatures, the evaluation of several cover gases in storage tanks and continued and expanded operation of the molten salt corrosion test loops at CRTF. Dismantling and inspection of MSEE molten salt steam generator for abnormal corrosion effects.

Liquid Sodium Recommendations Follow:

Reheater, $1.0 mil. While sodium-to-water steam generators have been developed for the evaporator and superheater mode of operation, operation in the reheater mode is sufficiently different so that development and testing is required. There are no U.S. manufacturers of steam generators which operate in this mode. The use of reheat will allow a significant improvement in turbine efficiency for solar systems and will allow them to be more competitive with fossil-fired plants. This development activity would include the design and analysis of plant sized reheater units for operation at 1100°F sodium temperature followed by the fabrication and test of a prototype test unit.

2nd Generation Receiver, $1.0 mil. A second generation receiver is a necessary adjunct to the development of the air/rock storage concept, since this storage system must operate at slightly higher temperatures (1100°F to 1200°F). Several materials would be evaluated for this application and a test unit designed and fabricated. The receiver would be tested at flux levels up to 1.50$\overset{M}{0}$W/M^2, with sodium outlet temperatures not to exceed 1200°F.

Air/Rock Storage, $1.0 mil. The economic viability of an all-liquid type central receiver concept as an energy option will be greatly enhanced by the development of the air/rock storage concept which shows the potential for economical quasi-baseload type of operation. The technical performance and operating characteristics of the air/rock system needs to be verified before the private sector can take over the engineering development and application. The operating and economic benefits associated with a long duration storage system with up to 12 hours of full power operating capacity would be analyzed. A system designed to operate with 1100°F air would be tested to determine storage charge and discharge capability, durability of the rocks, temperature distributions, and pressure drop.

c) In order to reduce operating costs of both small and large scale plants, commercial development and testing of automated, unattended control systems is required. It is envisioned that this effort would culminate in test loops either at Solar One or CRTF. A $1.0 mil funding level is recommended for FY '85.

2. EXPERIMENTS

a) Solar One Operations, Maintenance and Analysis

This item provides $4.6 mil for the continued operation of Solar One test and evaluation activities, and initiating the utility power production phase.

(1) An analysis of test data to compare predicted and actual plant parameters to verify design performance. Developing operating strategies to increase plant output and improved economics.

(2) Collector (heliostat) tests and evaluations to derive beam pointing, beam quality, and reflectivity data. Heliostat cleaning requirements will be established.

(3) Plant maintenance evaluations will be conducted, including the analysis of the reliability of equipment, the identification of preventive maintenance needs, and receiver repair activity.

(4) "Lessons learned" documentation for design, construction, operational phases and technology transfer.

b) MSEE Operations & Test

Molten Salt Electric Experiment Operations & Test: $2.4 mil. The Molten Salt Electric Experiment, made operational in 1984, requires continued support in the advanced testing phase. Design and construction (Phase I) will be completed in 1984. Operational testing and training (Phase II) is planned for completion in GFY'84. A Phase III program--advanced testing--is recommended for GFY'85. This testing will be conducted by teams of user and designer/manufacturer personnel and will, upon completion, provide a greater degree of understanding of systems/hardware uncertainties to users. This program provides for both technology transfer and for development of a broader base of experimental experience from which future molten salt technology development requirements can be defined.

c) Large Scale Experiments

This item provides $10.3 mil in FY'85 for direct support of one or more industrial team projects. This will provide a relatively low level of government cost sharing for a portion of the R&D effort required and will allow industry to meet otherwise unachievable project financing hurdles and to proceed with projects currently on the board. Follow-on funding at a level of $15 mil/yr for FY'86 and FY'87 will complete this requirement and bring STCR technology into private sector acceptance.

d) Small, Remote System Concepts:

International applications of STCR technology in remote locations is being explored by many governments including Canada, France and Switzerland. The smaller/remote locations are potentially suitable for STCR technology since current electric generation costs are on the order of 16-20¢/KWh. An amount of $0.5 mil is recommended for cooperative, exploratory studies of smaller system and component applications for remote deployment.

C. DISTRIBUTED COLLECTOR TECHNOLOGY DEVELOPMENT

1. PARABOLIC DISH

The parabolic dish technology development program of $11.9 mil shall continue research in the electric and thermal applications. Dish electric module development shall consist of $2.5 mil for the brayton module developments and $1.7 mil for the terrestrial solar application of the NASA sponsored 25 KW free piston Stirling engine. The shift of lead center responsibilities shall provide a shift to thermal applications of parabolic dishes and consequently fund $1.2 mil for such activities with $1.5 mil for operations of Distributed Receiver Test Facility. The Innovative Concentrator Program started in FY 84 shall continue at $3.0 mil. The Small Community Solar Experiments shall be supported with a total of $1.0 mil reserved strictly for operations and maintenance of these systems for a sufficient period of time to fully gain the data and experience associated with this project(s). In the same context, $0.5 mil shall be provided to continue data collection at selected representative parabolic trough facilities. As presented in the President's budget, $0.5 mil shall be provided for capital equipment.

2. PARABOLIC TROUGH - Components, Materials & Performance

A funding level of $0.5 mil is recommended for completion of the operating phase of existing IPH and MISR projects, to obtain data from trough systems which remain operational and to support refurbishment and/or retrofit of specific systems which represent commercial prototypes. Until first commercial projects are in operation, existing DOE funded systems are the only ones available for use as industrial marketing tools. For this reason, their efficient performance and continuing operation is mandatory.

D. PLANNING AND PROGRAM SUPPORT

1. Approximately $1.7 mil is recommended by the industry for allocation in the area of planning and coordination of solar thermal activities. These activities should be directed toward all technologies, with emphasis on short term and long term planning, analysis, assessment of technical and economic issues, and program evaluation and documentation to ensure a balanced and effectively prioritized program. These activities are conducted by a core staff comprised of personnel from several DOE labs with support from other subcontracted organizations uncoupled from any one solar technology to obtain unbiased results. The industry opposes activities dealing with cost goals, since such activities tend to have a negative effect on private-sector marketing activities.

The planning and documentation effort resulting in preparation of Annual Operating Plans, Multiyear Program Plan, Annual Evaluation Report, etc., are important for the management and evaluation of the current program, as well as planning for future research and development.

This activity is expected to continue in out-years at approximately this level.

Senator **Evans**. Thank you. We won't wait for the rest of the panel to testify before we ask questions in light of your—I understand you have to leave by 11 o'clock. Perhaps I will get at least a couple of questions first.

The budget as you went through it rather rapidly, the request is $17 million over the administration. Let me go over that briefly again with you. It is $14 million for research, $17 million for the central receiver, $12 million for the parabolic dish, and what is the remainder of that? This only gets me to about $48 million.

Mr. **Hildebrandt**. $1.7 million for planning and project support; there was also $12 million for—I think the balance of that is large-scale, two large-scale experiments required for risk reduction in the area of receiver components, either a molten salt or a sodium receiver system.

Senator **Evans**. Without trying to match those currently against the administration's budget, where in your proposed budget does the extra $17 million lie? Is it a little bit of everything or is it focused in one area that the administration has left out?

Mr. **Hildebrandt**. About half, a little bit of everything, and then the added item above the administration budget is a large-scale experiement as I say for risk reduction in the crucial central receiver component. The heliostat and general system are well understood, but to move into utilities and third party venture groups accepting this type of operation, they are very cautious about going to immediately full-scale 50 or 100 megawatt experiment, and we are needing an additional large-scale experiment as outlined in the costing.

Senator **Evans**. The large-scale experiment is the receiver, receiver components generally?

Mr. **Hildebrandt**. Yes, the receive storage; we understand the steam technology. We understand the heliostat and the control, but the risk factor is the receiver storage aspect.

Senator **Evans**. If we understand the heliostat and that element pretty well, then why a suggestion for $17 million for central receiver and $12 million for parabolic dish if receiver, if that sort of thing is fairly well understood?

Mr. **Hildebrandt**. Why the $12 million for parabolic dishes?

Senator **Evans**. I thought you had indicated that that element of the total system was better understood than was the receiver component, the transfer of the energy and the use of energy where the large-scale experiments were going to be conducted.

What is contemplated with the $17 million that you are advocating for central receiver and $12 million for parabolic dish? What is going to be done with that money?

Mr. **Hildebrandt**. Large-scale experiment is the major factor of that. There is in general the ultimate increase requested above the administration budget in the dish area and in the general central receiver research area. The single item, largest item, was the $12 million experiment, the large-scale experiment.

Senator **Evans**. So perhaps I will have to look, I am just looking at your sheet here. It is broken down into a number of different elements and I guess you would lump them together under the general term central receiver or parabolic, but there are separate elements that go to make up those amounts of money. We may have to get into further written questions to elicit some more details.

Mr. **Hildebrandt**. I thought you were referring to this document. You are really referring also to the complete budget.

Senator **Evans**. I was listening to your testimony and the dollars you set aside, and then I have in front of me the other, more detailed layout. It is hard to put the two together. We will have to do it through some written questions.

Mr. **Hildebrandt**. I will be happy to do so.

Senator **Evans**. What would you consider—it looks as if we are in difficulty in funding almost anything this year. We are looking for deficit reduction programs. Congress will be spending most of the next month trying to figure out how to make their first shot at deficit reduction.

If we can't come up with the total amount of money that you are requesting in solar energy research, which portions of your suggestion are the highest priority? What must be done?

Mr. **Hildebrandt**. There is a small section or a segment of the continuing research I think that is needed to have done, and also you need the industry interest in moving central receivers into the sector, so I would say I would believe that the most crucial item lies in the central receiver components and moving those into risk reduction and being able to get into the third party interest groups and having the utility acceptance.

Utilities are naturally very, very conservative. They want to make sure the large-scale units work and not charge their ratepayers.

I would say most important in general here is we have to have a program, and to have a program, we have to have an industry moving this technology to the floor.

Senator **Evans**. You mentioned in your testimony the success of Solar I, the electrical output and the amount of energy which has been produced.

I know it is difficult to get any kind of cost of energy production on an experimental plant, but do you have any idea at all if you were now just kind of set aside investment that has been made on the research side and you were to start from scratch and just build the same kind of plant with what you know now, duplicative with the construction costs necessary, at what cost could energy be produced?

Mr. **Hildebrandt**. Well, I see an economic analysis run out on Solar I, on the exact cost of the present plant which was $141 million—the very first of a kind. It is very expensive. That produced energy at about between three and a half and less than four and a half, between three and a half and four times what the cost of oil energy would be produced from an oil plant. That was a year ago, so I haven't included any decrease in oil cost. That is for that specific plant.

Now if you went and put up a second plant, I would feel comfortable in saying the cost could certainly be cut even on that particular scale. The reason it would be cut a lot more is that you are still only producing 1,800, 2,000 heliostat, that you see the precipitous drop start taking place, a factor of, factor of two less.

Senator **Evans**. OK. We may have other questions that we would submit. We would be appreciative of additional information if you have those questions. We appreciate very much your coming and being with us today, and you are certainly welcome to stay as long as you can. I understand, though. Whenever you feel it necessary to leave, please feel free to do so.

Mr. **Hildebrandt**. I am delighted to be here. I have a commitment to be on the west coast for about 4 o'clock.

Senator **Evans**. I think you better get started!

Mr. **Hildebrandt**. Thank you.

Senator **Evans**. The research we haven't completed yet is how to speed up transportation.

Mr. **Hildebrandt**. Thank you.

Senator **Evans**. Dr. Stuart Ridgway, would you like to go next? Dr. Ridgway.

STATEMENT OF DR. STUART L. RIDGWAY, PROGRAM MANAGER, MIST FLOW HEAT ENGINE, R&D ASSOCIATES

Dr. **Ridgway**. I thank the committee for the opportunity to present my views and the views of the R&D Associates on the appropriate direction for ocean thermal energy research.

We all agree that the ocean thermal resource, that is, the temperature difference between the surface and the depth of the topical ocean, is a resource that has large quantities of available energy, but so far, the projected costs of the machinery to utilize this resource have discouraged many from following it further.

Estimated capital costs of the presently favored vapor flow power systems appear to be in the range of $7,500 per kilowatt of electrical capacity, and the less completely developed Claude open cycle will not be less.

Faced with these prospects, the administration has chosen to contract OTEC research funding from a rate on the order of $30 million per year in 1979 to $5 million per year in fiscal 1984. The budget request for fiscal 1985, Mr. Collins told us this morning, for DOE ocean systems is $3.5 million.

However, there has been a recent breakthrough in the technology of ocean thermal energy conversion that promises greatly reduced capital cost. This breakthrough is known as the mist lift process—a modification of the Claude open cycle OTEC has been conceived that needs neither heat exchangers nor a giant vapor turbine, and projected capital costs have tumbled as a result.

DOE-funded proof of principle experiments in a four meter high lift column completed in early 1981 demonstrated that the coupling between the vapor that lifted water droplets and the water droplets was sufficient to achieve lifts between 50 and 80 meters under OTEC temperature conditions, and the indications were that the limit had not been reached. The technical details, sir, are reported in the reprint of the paper by Dr. C.K.B. Lee and myself. That was published in May of last year, and I would like it to be entered into the record.

Senator **Evans**. It will be entered into the record at this point.

Dr. **Ridgway**. Thank you.

[The above-mentioned paper follows:]

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Vapor/Droplet Coupling and the Mist Flow (OTEC) Cycle

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The present experiments have demonstrated that water droplets (~ 200-μm dia) can be lifted to substantial heights (~ 50 m) by their own vapor produced in flashing over temperature differences typical of the tropical seas. The coupling between the vapor and droplets is found to be excellent. The efficiency for momentum coupling is over 90 percent, and that for energy coupling is shown to vary inversely with the slip ratio. For the conditions in the present experiments, it varies from 50 to 80 percent. The momentum transfer is correlated with an interaction parameter which is the product of the liquid fraction, the slip, and the amount of flashing. For the high vapor flow cases, the pressure difference across the lift column is found to be proportional to the interaction parameter. The relevance of the two-phase flow to a class of open-cycle ocean thermal energy conversion (OTEC) schemes is considered, and the implications of the observed strong vapor/droplet coupling to the feasibility of the mist-flow OTEC cycle are discussed.

Introduction

The temperature difference between the surface and the depths of the tropical seas is a potential source of low cost energy. D'Arsonval [1] suggested exploiting this temperature difference with a Rankine cycle that used a working fluid such as sulphur dioxide. This is known today as a closed-cycle system, the cost of which depends mainly on the cost of the large heat exchangers. Claude [2] was first to design and build an open-cycle system. In the Claude cycle, the warm surface water evaporates in an evacuated chamber, the vapor passes through a turbine to do work, and is condensed in a second chamber by cold water from the depths. The extremely low density of the vapor requires a very large turbine.

In 1975, Beck [3] proposed an open cycle that avoids the use of a vapor turbine. He proposed a vapor lift pump where the warm surface water is allowed to flash in a vacuum chamber into a bubbly mixture which naturally underwent transition to slug flow and then to dispersed flow. The water collected at the top of the vapor lift pump is allowed to fall over the lifted height to do work in a water turbine. Another cycle, proposed the same year by Zener and Fetkovich [4], is known as the foam lift cycle. It uses a detergent to create and stabilize a bubbly foam while the water is flashing. The expansion of the foam is utilized to lift the water, which, after foam-breaking, falls to drive a water turbine.

In 1977, Ridgway [5] proposed the mist flow cycle. In this cycle, the warm water at the surface of the ocean is first allowed to fall for a depth of ~100 m, and the potential energy released is extracted by a hydraulic turbine. Then the warm water is lifted back to the ocean surface by its thermal energy. The lifting is achieved by spraying the warm water as a uniform mist of fine droplets (~200-μm dia) up an evacuated lift column. The vapor produced in the flashing of the water drags the droplets back to the ocean surface. Cold water from the depths of the ocean (e.g., 700-m deep) is pumped to the ocean surface and sprayed into the condenser at the top of the evacuated lift column to condense the flashed

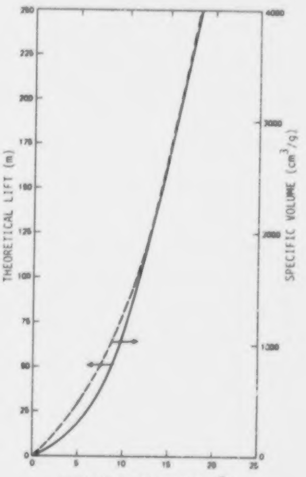

Fig. 1 Theoretical lift and specific volume versus temperature difference $T_l - T_e$, for T_l = 25°C

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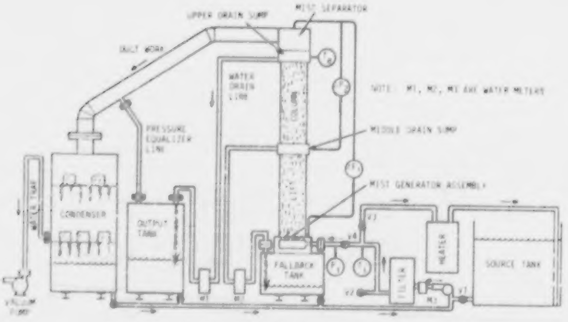

Fig. 2 The bench-scale mist lift experiment apparatus

vapor to maintain the upward vapor flow. The mixture of lifted droplets, condensate, and cold water is then returned to the ocean at a convenient depth.

The common feature among these three lift cycles is the use of two-phase flow to achieve the desired lift. In fact, the success and failure of each of these cycles depend largely on the choice of the two-phase flow regime. The amount of theoretical work available (in terms of distance lifted against gravity) from the isentropic expansion of water from the saturation line to the two-phase region as a function of the temperature difference and specific volume is plotted in Fig. 1. Most of the work is done at specific volumes (of the two-phase mixture) >500 cm^3/g. The small liquid fraction of the final mixture determines the appropriate two-phase flow regime to be the mist flow regime. Furthermore, due to the large interface area provided by the droplets, the coupling between the phases is excellent.

This paper presents the experimental results of a small-scale experiment where the coupling process is studied in a (0.24-m × 0.375-m) rectangular column 4-m tall. It is shown that the energy imparted to the droplets in this short column is sufficient to carry them to substantial heights (many tens of meters).

Experimental Apparatus and Procedure

The apparatus (Fig. 2) comprises six major components: a source tank, a fallback tank, an output tank, a condenser, a vacuum pump, and the plexiglass lift column. Warm water from the source tank is led to the mist generator assembly and forced through the nozzle plate, which produces numerous tiny jets of water that break up into droplets just above the mist generator. Simultaneously, vapor flashed from the jets accelerates the droplets up the lift column. As mentioned in the introduction, since most of the work is done at large mixture specific volumes, the ratio of nozzle area to total area of the mist-generator is chosen such that initial mixture specific volumes of ~ 1000 cm^3/g are achieved.

Droplets that strike the wall will coalesce in a water film that drains past the mist generator into the fallback tank. Most of the droplets, however, continue up the lift column. At the top, the droplets are separated from the vapor and allowed to drain into the upper drain sump and then the output tank. The vapor is ducted into the ice-filled tank where it condenses. In the present experiments, the ice charge suffices for 20 min of operation. The experiment is started by opening valve V4, allowing the warm water to flow into the mist-generator assembly. The water injection pressure is controlled by adjusting valve V4. The pressure difference across the lift column is measured by a manometer using ethylene glycol. The pressure difference across the upper half of the lift column is measured by a differential pressure gauge (manufactured by Setra Systems), which is sensitive to pressure changes of 1 Pa and has a range of 0 to 138 Pa. The

Nomenclature[1]

C = proportionality constant
c_p = specific heat
C_v = velocity coefficient
F = momentum flux of water jets, see equation 1
F_{dg} = drag force per unit volume between the vapor and the droplets
F_{wd} = droplet momentum losses per unit volume due to wall effects
F_{wg} = Momentum losses for the vapor due to wall effects
G = mass flux
g = acceleration due to gravity
h = column height
h_{fg} = latent heat of vaporization
L_e = effective lift height

$\dot{m}$ = mass flow rate
P_e = exit pressure
P_i = injection pressure
$\bar{S}$ = slip ratio $(\bar{S} = (V_{ge} + V_{gi})/(V_e + V_i))$
T_B = flashdown temperature
T_e = exit temperature
T_i = injection temperature
$\bar{V}_d$ = transport velocity (average droplet velocity)
V_e = droplet velocity at exit
V_i = injection droplet velocity
V_{gi} = vapor velocity
V_{ge} = exit vapor velocity

V_S = slip velocity

$$\left(\bar{V}_s = \frac{V_{ge} + V_{gi}}{2} - \frac{V_i + V_e}{2}\right)$$

x = quality
z = vertical distance
α = void fraction
β = liquid fraction
ρ = density
η = interaction parameter
ϵ = energy coupling efficiency
ξ = fraction of momentum shared by the vapor flashing in a one-dimensional flow (see reference [6], equation (3.49))

Subscript

d = water droplets
g = vapor

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[1] Bar over a variable denotes arithmetic average.

temperature of the mist at the top of the column is measured with a YSI precision thermistor encased in a thin-walled glass tube and inserted into the flow.

The velocity coefficient of a mist-generator plate sample was determined by measuring the momentum flux, F, and the mass flux, $\dot{m}$, out of the sample at a known nozzle plate pressure differential, ΔP. The velocity coefficient is given by

$$C_v = F/\dot{m}(2\Delta P/\rho)^{1/2} \tag{1}$$

A typical nozzle plate, made of a 0.25-mm-thick stainless steel perforated plate with electron-beam-punched holes distributed on a square matrix with a 1.8-mm pitch, was tested. The flow entered the side with the large diameter (0.175 mm) and exited at the side with the smaller diameter (0.1 mm) just like the flow through a nozzle.

The equipment to measure the quantities in equation (1) consisted of a water supply line, a Bourdon pressure gauge (0–400 kPa gauge), a 90-deg turning plate, and a spring scale (0–500 g range). The water jets quickly break up into a mist of tiny droplets due to Rayleigh instability. The diameter of the drops is twice that of the jets. The jets are directed downward toward a 90-deg turning plate placed on the spring scale. The momentum flux is measured as the difference between the scale reading with and without the jets. The mass flow rate is measured by collecting the water over a minute.

The results are given in Table 1. The clogged mist generator had been submerged in a tank of Santa Monica City water for a month. Some clogging of the nozzles was visually observed; however, the effect on the velocity coefficient was small. The clogging in sea water has not yet been investigated. The results indicate that (*i*) the flow is proportional to the square root of the pressure difference, and (*ii*) the velocity coefficient is 0.95 for a clean nozzle plate. The expected hydraulic efficiency of the mist generator is therefore approximately 0.9.

Data Reduction Procedure and Error Bounds

The one-dimensional momentum equation for the vapor appropriate for the present experimental condition in the lift column consists of the vapor acceleration term, the pressure force term, the gravity term, the vapor/droplet interface drag term, F_{dg}, the wall friction term, F_{wg}, and a term representing the momentum change due to flashing, and is

$$\alpha\rho_g V_g \frac{dV_g}{dz} = -\alpha\frac{dP}{dz} - \alpha\rho_g g - F_{dg} - F_{wg} - \xi(V_g - V_d)G\frac{dx}{dz}\,, \tag{2}$$

$$1 \qquad\qquad 100 \quad .01 \quad ? \quad << F_{dg} \qquad 1 \qquad \mathrm{Pa/m}$$

Table 1 Measured velocity coefficient

	Momentum flux F, kg-m/s^2	Mass flux $\dot{m}$, kg/s	Gage pressure ΔP, Pa	Velocity coefficient C_v
Clogged injector plate	8.52	0.0948	4.15×10^5	0.94
	4.61	0.0667	2.52×10^5	0.93
Clean injector plate	13.63	0.15	4.15×10^5	0.95
	8.23	0.113	2.72×10^5	0.95

Table 2 Mist-lift experiment results (velocity coefficient = 0.9)

Run No.	T_l °C	P_i (ABS) Pa $\times 10^{-5}$	T_g °C	ΔP_1 Pa $\times 10^{-2}$	ΔP_2 Pa $\times 10^{-2}$	Average slip vel. $\bar{V}_s$, m/s	Average quality $\bar{X}$	Average liquid fraction $\bar{\beta} \times 10^4$	Mass flux G kg/m^2 − s	Coupling eff. ϵ	L_v m
20	35.8	1.01	13.0	1.8	0.78	13.9	0.0372	5.5	10.9	0.59	34.3
21	35.8	1.70	13.1	2.7	1.30	17.0	0.0365	5.8	14.2	0.59	48.7
23	35.8	0.67	12.3	1.6	0.63	11.7	0.0385	4.8	8.9	0.61	34.0
24	38.9	1.01	10.7	1.5	0.70	30.5	0.0463	5.9	10.9	0.38	26.0
25	35.6	0.51	13.1	1.3	0.53	7.80	0.0370	2.2	7.7	0.67	27.7
26	39.2	0.68	13.0	1.5	0.65	14.6	0.0431	3.6	8.9	0.55	30.6
27	39.2	0.51	13.1	1.1	0.47	13.6	0.0433	5.1	7.7	0.52	20.9
28	38.9	0.41	13.4	0.86	0.28	11.9	0.0536	4.2	6.8	0.51	16.3
51	37.2	1.3	11.7	4.0	2.0	26.9	0.0397	5.4	17.4	0.54	81.0
52	37.2	0.47	12.5	0.7	0.2	15.0	0.0412	5.9	7.4	0.44	12.5
53	27.8	2.0	11.0	1.7	0.9	16.2	0.0267	6.9	15.4	0.59	27.7
54	27.8	1.3	9.9	1.7	0.6	15.3	0.0285	6.0	12.7	0.58	30.9
55	27.8	.08	8.7	1.9	0.4	10.8	0.0301	4.7	9.8	0.66	44.6
56	27.8	0.7	8.1	2.0	0.3	9.10	0.0309	4.1	8.9	0.70	53.1
57	27.8	0.5	7.8	1.8	0.2	7.10	0.0315	3.6	7.7	0.74	52.9
61	25.0	2.36	14.9	1.21	0.3	~0.0	0.0164	8.1	16.9	1.0	14.2
62	25.0	2.02	10.3	1.21	0.6	16.7	0.0238	3.5	15.6	0.55	14.5
71	46.1	0.3	12.3	0.88	0.2	11.3	0.0567	4.3	6.1	0.56	24.9
100	40.0	0.46	13.1	1.3	0.54	18.9	0.023	6.18	8.9	0.43	21.4
101	30.5	1.01	8.6	2.2	0.71	24.23	0.018	5.76	12.0	0.46	38.2
102	30.0	1.01	9.4	2.0	0.68	21.04	0.017	6.04	12.0	0.49	32.8
103	30.0	1.01	9.9	2.0	0.65	18.89	0.017	6.03	12.0	0.51	32.9
104	30.0	1.35	10.8	2.2	0.74	18.58	0.016	6.42	13.9	0.54	34.3
105	30.0	1.35	11.3	2.2	0.74	16.37	0.016	6.42	13.9	0.57	34.3
106	30.0	1.35	11.6	2.2	0.74	15.16	0.016	6.42	13.9	0.59	34.3
107	30.0	1.70	12.0	2.7	0.89	14.38	0.015	6.47	15.6	0.63	40.8
108	29.5	1.70	12.1	2.7	0.88	12.6	0.015	6.47	15.6	0.66	40.8
109	29.5	2.05	12.8	2.8	1.05	11.56	0.014	6.76	17.1	0.68	40.6
110	37.2	2.3	11.6	5.5	1.94	26.45	0.022	5.42	18.2	0.56	101.5
111	24.4	1.01	8.2	1.7	0.50	16.24	0.014	6.50	12.0	0.53	25.5
115	24.4	1.35	11.4	1.5	0.50	7.64	0.011	7.24	13.9	0.72	21.4
117	24.4	1.70	12.1	1.3	0.51	7.74	0.011	7.91	15.6	0.72	16.7
119	25.0	2.2	11.4	2.2	0.77	10.49	0.012	7.39	17.9	0.70	29.8
120	24.4	2.2	10.2	2.6	0.83	12.19	0.013	7.03	17.9	0.68	37.6
121	24.4	2.2	9.5	3.0	1.08	14.25	0.013	6.79	17.9	0.65	43.8
122	24.4	2.2	8.2	2.8	1.00	22.59	0.014	6.95	17.9	0.53	39.5
123	24.4	3.4	10.2	3.9	1.3	12.02	0.013	7.04	22.1	0.72	54.7
124	24.4	3.4	10.2	3.4	1.3	14.73	0.013	7.34	22.1	0.67	44.9
125	23.9	3.7	10.6	3.9	1.5	9.49	0.011	7.21	23.2	0.77	53.3
126	23.9	3.1	11.1	2.8	1.0	9.09	0.011	7.49	21.0	0.75	36.7

Table 3 Relative errors calculated based on Run 20

Quality	Error in measurement	Percent
P_i	33 kPa	–
T_i	0.28°C	–
T_e	0.2°C	–
ΔP_1	10 Pa	–
ΔP_2	1 Pa	–
C_i	–	±4[7]
C_D	–	– same as C_i
$\dot{m}$	–	±8.3
$V_e - V_i$	–	±3.3
n_i	–	±13.3

where α is the void fraction, x is the quality, and ξ is the fraction of the momentum change due to flashing that is expended in the vapor stream. Listed below each term is the estimated order of magnitude of that term either from direct measurements or from calculations. The vapor velocity and the quality in the lift column can be calculated using a heat balance and the steam table. The wall friction term is expected to be much smaller than the interface drag term since the surface area of the wall, even with a wavy liquid film on it, is substantially less than that of the droplets. The pressure drop is a measured quantity, and the gravity term is negligible. Thus equation (2) can be approximated by

$$\frac{dP}{dz} \cong -F_{dg} \tag{3}$$

recognizing that $\alpha \sim 1$ in the present experiments. This means that over 90 percent of the force exerted by the vapor is spent in dragging the droplets.

Next, consider the momentum equation for the droplets:

$$\beta\rho_d V_d \frac{dV_d}{dz} =$$

?

$$-\beta\frac{dP}{dz} - \beta\rho_d g + F_{dg} - F_{wd} - (1-\xi)(V_g - V_d)G\frac{dx}{dz} \tag{4}$$

.01 1 100 1 1 Pa/m

Again, the orders of magnitude of the terms are given below each term. All the terms, except the interface drag and the wall friction, are calculated by the same method. The interface drag term is taken to be dP/dz from the analysis of the vapor momentum equation. The wall friction term requires some physical interpretation. In the lift column, the wall acts as a sink for the droplets. The momentum of the droplets that hit the wall is lost. The quantity of droplets collected at the wall is observed to be about 3 percent of the total flow per meter of height. Therefore, the momentum loss is

$$F_{wd} \cong 0.03 G_d \bar{V}_d \tag{5}$$

where G_d is the droplet mass flux, and $\bar{V}_d$ is the droplet velocity averaged over the column. The actual momentum loss is less than this since most droplets strike the walls in the lower half column. These droplets have not been worked on by the vapor to the extent that they have acquired a velocity of $\bar{V}_d$. The loss of liquid due to the wall effect actually reduces the liquid fraction in the main-stream such that for the same pressure difference a larger velocity is imparted to the droplets in the mainstream. From this analysis it is clear that over 90 percent of the interface drag goes to accelerate the droplets and a few percent to overcome gravity. Equation (4) can therefore be approximated by

$$G_d \frac{dV_d}{dz} = -\frac{dP}{dz} - \beta\rho_d g \tag{6}$$

Integrating over the column, equation (6) becomes

$$G_d(V_e - V_i) = \Delta P_1 - \int_B^T \beta\rho_d g dz \tag{7}$$

where V_i and V_e are the velocities of the droplets at the inlet and at the exit respectively; ΔP_1 is the pressure difference across the column, and $\int_B^T$ denotes the integral from the bottom to the top. Thus, a simple estimate of the average transport velocity will determine the amount of momentum coupled to the droplets in the column. The recorded measurements were the injection pressure, P_i, and temperature, T_i, the pressure difference across the entire column, ΔP_1, the upper half column, ΔP_2, and the top temperature, T_e.

The data reduction procedure begins by calculating the saturation pressure at the top of the column based on T_e. Then the pressure at the bottom of the column, P_B, is determined using ΔP_1. The pressure difference $P_i - P_B$ is used to calculate the mass flow rate, $\dot{m}$, and the injection velocity, V_i. Finally, the effective lift height is given by

$$L_e = \frac{V_e{}^2 - V_i{}^2 + 2gh}{2g}$$

where h is the column height. The measured and the calculated data are tabulated in Table 2 along with the corresponding two-phase flow parameters.

An analysis was performed, based on the errors in the measured quantities, to determine the errors involved in the calculated quantities. Table 3 presents the results. The magnitudes of these errors are larger than those incurred by the neglect of the minor terms in the momentum balance equations; therefore, the use of the simplified data reduction procedure is justified.

Discussion of Results

The results of the present experiments clearly demonstrate that a mist of droplets produced by the present mist generator can be lifted to substantial heights by its own flashing-generated vapor.

From the analysis of the momentum equations in the previous section, it is observed that almost the entire pressure drop in the vapor is invested in the acceleration of the droplets. An energy coupling efficiency can be defined by the ratio of energy gain in the droplets to the corresponding loss in the vapor, i.e.,

$$\epsilon = \frac{G}{\Delta P}\,\frac{V_e^2 - V_i^2 + 2gh}{2\bar{V}_g} \tag{8}$$

and, using equation (7)

$$\epsilon = 1/\bar{S} = \bar{V}_d/\bar{V}_g \tag{9}$$

Equation (9) indicates that the energy coupling efficiency is inversely proportional to the average slip ratio, $\bar{S}$. From Table 2, the data also reveal that an energy coupling efficiency of ~ 70 percent was achieved although no attempt was made to maximize it. It is expected that efficiencies of 80 percent will be easily achieved when the experimental conditions are optimized.

Since the pressure difference is a direct measure of the momentum transfer (or coupling) between the vapor and the mist, it would be advantageous to correlate it with other two-phase flow parameters. Physically, it is expected that the pressure difference would depend on the liquid fraction, β, the slip velocity, V_s, the vapor flow, the droplet size spectrum, the corresponding velocity spectrum (both dependent on the amount of coalescence and breakup), as well as the amount of flashing during the transport. For a given size spectrum the liquid fraction can be used as a measure of the relative distance between droplets and therefore as a measure of the probability of coalescence. It is also a measure of the amount of liquid available for the vapor to lift.

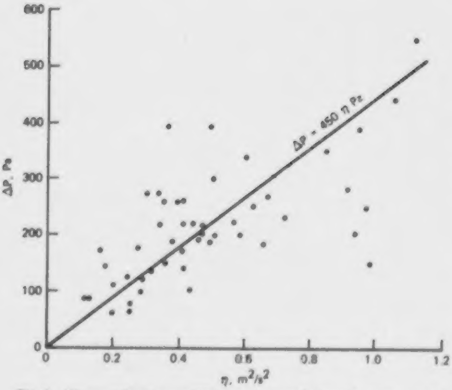

Fig. 3 Measured pressure difference versus interaction parameter

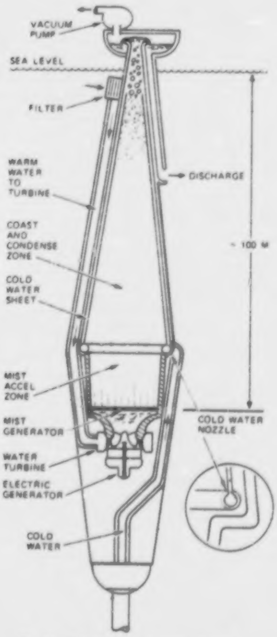

Fig. 4 The mist flow power plant

Coalescence and breakup are governed by the collision cross sections, which depend mainly on the radii of the interacting droplets and their velocities of approach. Higher approaching velocities reduce the probability of coalescence.

The large number of variables involved makes it difficult to obtain a simple correlation. However, if only the high vapor flow cases are considered, it is likely that one can neglect the spectral evolution effects since the transport time of the droplets is reduced. When less time is available for the motion, the droplets would have less chance to collide during the transport. Moreover, since the approaching velocities of the droplets are much higher, the breakup of coalesced droplets becomes more probable upon colliding with another droplet. Hence, the droplet spectrum is more likely to stay approximately the same throughout the transport. For a slip of 20 m/s (Re ~5 in the experiments) deviation from Stokes drag is small, and therefore the drag is approximately proportional to the slip velocity. Since vapor flow is a measure of the amount of energy available, it is expected that the momentum transfer is proportional to the vapor flow. These arguments suggest the use of a simple parameter to correlate the interaction between the vapor and the droplets

$$\eta = \hat{\beta} \hat{V}_s V_{ge} \tag{10}$$

where

$$V_{ge} = G c_p \Delta T / (h_{fg} \rho_g)$$

The exit vapor velocity is used rather than the average because it is proportional to the temperature difference, ΔT, in the flashing, which represents the total available energy. Here, c_p is the specific heat, h_{fg} is the latent heat of vaporization, and ρ_g is the vapor density. It is postulated that for high flow, the pressure drop is proportional to the interaction parameter, $\Delta P = C\eta$. Note that this satisfies the limiting condition for the correlation that a zero pressure drop will result from the absence of any liquid in the column, or from lack of slip between the droplets and the vapor.

The data in Table 2 were scanned to select the high flow runs with $\Delta P_1 \approx 2\Delta P_2$. This ensured that equal amounts of work were done in each half-column. It was found that over 90 percent of the data with $V_{ge} \geq 20$ m/s did satisfy this requirement, which indicates that for most cases the work done was uniform throughout the lift column. The plot on Fig. 3. is the resulting correlation. It is accurate to ± 50 percent for these runs, except for Run 24.

Finally, no instabilities of the two-phase flow were observed in these experiments which would cause a rainout. Large variations in the injection pressure, which cause large changes in the flow rate, did not seem to affect the stability of the flow. Typically in these experiments the injection pressure was varied from ½ to 2 atmospheres and vice versa over a time period of a few seconds. The lower bound for the injection pressure was about 50 kPa below which rainout would occur. This value is dependent on the injection temperature. For example (Run 28), when the injection temperature was 38.9°C, the observed lower bound was 40 kPa; and for Run 71, when the injection temperatuare was 46.1°C, the lower bound was 30 kPa.

Experimental confirmation of the inferred exit velocity using equation (7) was obtained by suspending weights at the top and observing their liftoff by the momentum flux of the flow. These measurements verified equation (7) to within ±5 percent. The error in the calculated effective lift height is, therefore, no more than a few percent.

The Equivalent Power Plant

Using the present results, a power plant is designed based on a 4-m coupling section where the vapor/droplet interaction takes place, and a long section for the coasting of the high velocity droplets. The design parameters are: $A = 0.0871$ m² (area of present test section), $h = 4.0$m., $P_i = 480$ kPa, $T_i = 25$°C, $T_e = 9$°C.

The calculated quantities neglecting wall effects are: $G = 2.41$ g/cm²s, $V_i = 29.4$ m/s, $V_e = 46.0$ m/s, $V_{gi} = 41.9$ m/s, $\hat{V}_{ge} = 72.5$ m/s, $\hat{S} = 1.53$, $\hat{\beta} = 0.0006$, $\dot{x} = 0.0244$, $\hat{V}_s = 19.8$ m/s, $\Delta P_1 = 425$ Pa (equation (6)). L_e equals 108.0 m (this is height of coasting section); net height equals 63 m; gross power equals 1.30 kW, or 15 kW/m² of mist generator area. The expected losses expressed in meters of lift are: filter loss = 2 m, exit loss = 3 m, cold water pump = 18 m, and vacuum pump = 5 m, giving a total of 28 m of losses, or 44 percent of the net height. The net power is 0.73 kW, or 8.5 kW/m^2 of mist generator area.

Extrapolation to a Larger Plant Concept

In actual design, one is not limited to an acceleration zone 4 m in height that demands substantial acceleration (~10 to 20 g) over a short distance in order to exercise the full thermodynamic work of the cycle on the droplets. For an improved power plant design, it is better to operate at about 5-g mist acceleration over a longer distance. An improvement in the energy coupling results because a smaller slip ratio is used (see equation (9)).

A design based on these considerations is shown in Fig. 4. The central structure is the large evacuated duct in which the water is lifted a distance of about 100 m by the conversion of its heat energy into work. The warm ocean surface water enters through the filter at the left of the diagram, and then descends to the water turbine. Most of the pressure is removed from this water by the turbine to produce power. With the remaining pressure the warm water is then sprayed upward into the bottom of the duct.

The bottom 20 m of the duct comprises the mist acceleration zone. Cold water is introduced into the accelerated mist in the form of a circumferential converging sheet in the coast zone which is also the condenser. A vacuum pump removes noncondensibles at the top. The pressure difference between the start and the end of the acceleration zone drives the mist to a velocity of nearly 50 m/s. The converging cold water sheet merges with the accelerated mist to form a single jet which coasts upwards against gravity almost to a stop, and then overflows into a basin from which it then drains into the ocean. Note that coalescence of droplets in the coast zone does not change their upward momentum.

The accelerated mist is also used as a jet pump for the cold water. The heights of the acceleration and the coast sections are suitably chosen so that the momentum transfer from the mist to the cold water supplies the kinetic energy needed to carry the cold water to the barometric level, from which it is able to drain back into the ocean against atmospheric pressure. The use of the accelerated mist as a jet pump shortens the lift height by ~20 m, which is less than the amount of turbine head required to drive a mechanical cold water pump, so that the overall efficiency is increased. Moreover, some cost reductions should result from the replacement of the cold water pump by the jet pump and the shortening of the column relative to previous mist flow plant designs.

Conclusion

The major finding in the present experimental study is that a mist of droplets (~200-μm dia.) can be lifted to substantial heights (>50 m) against gravity by their own vapor generated from flashing. Considerations of the momentum balance indicate that over 90 percent of the total pressure drop is invested in accelerating the droplets. The efficiency of the energy coupling is theoretically inversely proportional to the slip ratio. For the present experimental conditions, the energy coupling efficiency ranged from 50 to 90 percent.

A correlation for the pressure difference, which is a direct measure of the momentum transfer from the vapor to the droplets, is

$$\Delta P = 450\eta \text{ Pa} \tag{11}$$

based on the parameter (η), which is a measure of the amount of interaction between the vapor and the droplets. Comparing with the data the correlation is accurate to within ±50 percent. It should be cautioned that the correlation would be expected to show a different proportionality constant if the initial droplet size or liquid fraction, i.e., the design of the mist generator, had been chosen differently.

These results imply that one could design a power plant based on the following conditions: (*i*) a short coupling section followed by a long coasting section, (*ii*) a high droplet transport velocity, and (*iii*) a high vapor flow. The equivalent power plant and an extrapolation to a larger plant concept have been presented.

Acknowledgment

This work was supported by the U.S. Department of Energy Subcontract No. 7613 monitored by Dr. Fang Chen and Dr. John Michel at Oak Ridge National Laboratory. The authors are indebted to the following individuals for their contribution to the experiments: Dr. Phil Hammond, Mr. John Ridgway, Mr. Alex Ridgway, and Mr. Min Kong Lau. The assistance of the personnel at Dynamics Technology is gratefully acknowledged.

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Dr. RIDGWAY. A further experiment under SERI sponsorship in the summer of 1983 demonstrated continuous operation of a mist lift column with the actual ocean resource at the Natural Energy Laboratory in Hawaii. The development program of the mist lift process is presently on hold. We have no money. We are eager to resume. The technical prognosis is excellent.

A recent cost estimate indicates that mist lift power plants should cost between $1,500 and $2,000 per kilowatt. These costs are competitive with those of nuclear plants and coal-fired plants with scrubbers and are less than half the costs anticipated for other OTEC schemes. The risks may appear as high since the process is so new, and the technical data base is scant. However, the expected rewards are large.

The development of advanced OTEC technology is an appropriate area for Government research and development. The largest rewards of the successful development and commercialization of OTEC will fall mostly to the consumers of electricity or energy-intensive products, so it is right and reasonable that they take on the development risk.

Utilities would have little or no payoff from their investment in OTEC research since their regulatory commissions will only reduce their rates if such a development succeeds, and may not even allow running R&D costs into the rate base if the development fails.

An equipment manufacturer has slightly more incentive to invest in such a development since he will profit by selling the new equipment. However, he is already profiting by selling oil, coal, or nuclear power generator technology, and he will lose some business as he gains some. He is reluctant to take the risk. The potential payoff is small and could even be negative.

The benefits of a successful OTEC development will be reaped by the consumers of the electricity, so we the consumers or taxpayers should take the risk.

The overall OTEC Research Program should emphasize cold water pipe development and heat and mass transfer for research for open cycle. The Mist Lift Research Program should be centered around an expanding data base of the fluid dynamics of the mist lift process and conducting a series of tests at increasing scale. Each set of tests should provide the technical base for designing the next larger experiment.

I wish to encourage the Congress to make funds available to DOE ocean systems so that they may accomplish their task of supporting the research that will make OTEC a reality.

Thank you.

[The prepared statement of Dr. Ridgway follows:]

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213 822-1715

TESTIMONY OF DR. STUART L. RIDGWAY TO BE DELIVERED BEFORE THE SENATE SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT

I would like to thank the Committee for the opportunity to present my views on Ocean Thermal Energy Research.

All agree that the Ocean Thermal resource is vast, but the projected costs of the machinery to utilize this resource have discouraged many. However, there has been a recent breakthrough in the technology of ocean thermal energy conversion that promises greatly reduced capital costs. This breakthrough is known as the Mist Lift Process. A modification of the Claude open-cycle OTEC has been conceived that needs neither heat exchangers nor a giant vapor turbine, and projected costs have tumbled as a result. The very large turbine that extracts the power from the vapor is replaced by a vertical vapor flow that lifts a mist of fine water droplets against gravity. The potential energy gained is extracted by dropping the water (before or after lifting) through a conventional hydraulic turbine. One possible arrangement is shown in the Figure.

DOE-funded, proof-of-principle experiments in a 4-meter-high lift column completed in early 1981 demonstrated that the coupling between the lifting vapor and the water droplets was sufficient to achieve lifts between 50 and 80 meters under OTEC temperature conditions, and the indications were that the limit had not been reached.

A further experiment under SERI sponsorship in the summer of 1983 demonstrated continuous operation with the actual ocean resource at the Natural Energy Laboratory of Hawaii. The development program is presently on hold. We are eager to resume. The technical prognosis is excellent.

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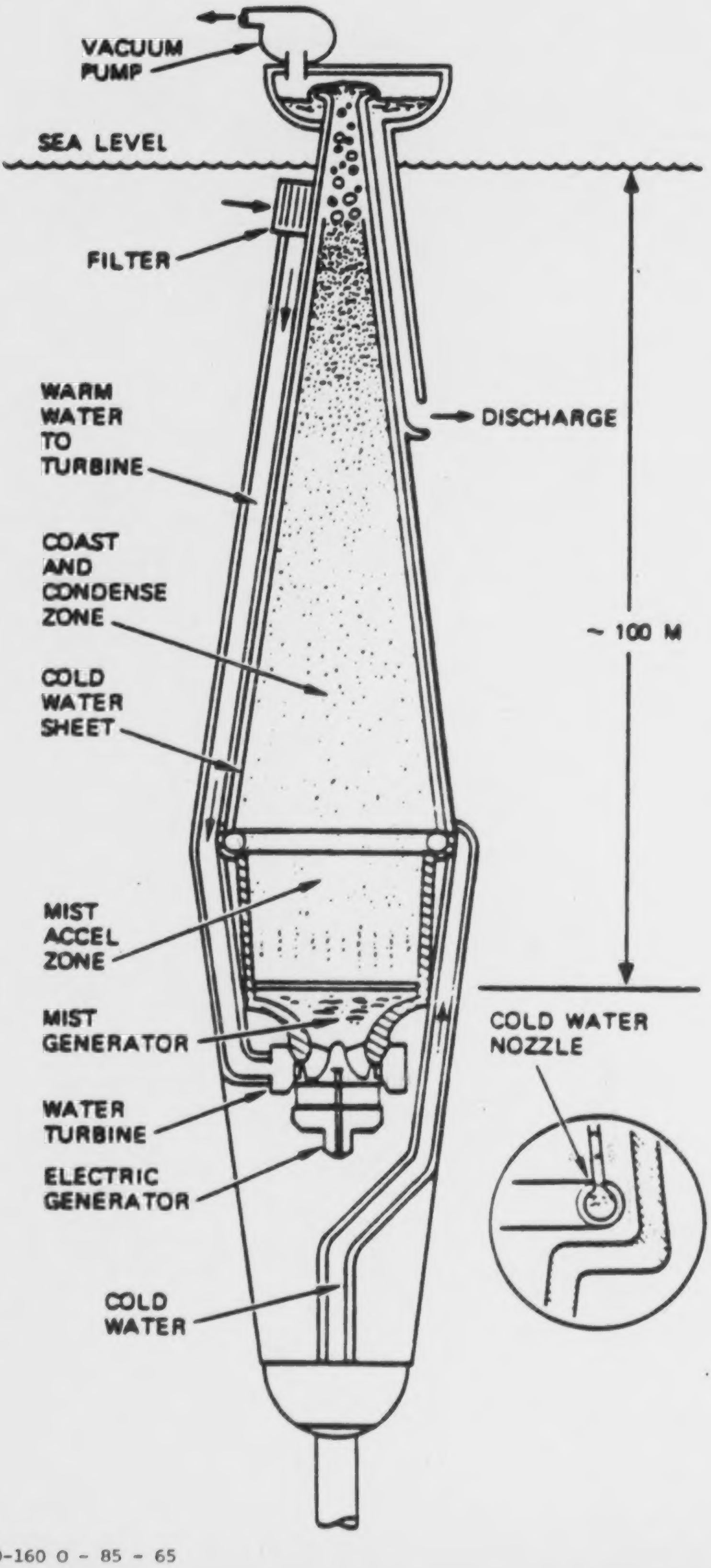
The benefits of a successful OTEC development will be reaped by all of us, so we the consumers should take the risks.

The overall OTEC research program should emphasize cold water pipe development, and heat and mass transfer research for open cycle. The Mist Lift research program should be centered around expanding the data base of the fluid dynamics of the Mist Lift Process and conducting a series of tests at increasing scale. Each set of tests should provide the technical base for designing the next larger experiment.

I would like to encourage the Congress to make funds available to DOE Ocean Systems so that they may accomplish their tasks of supporting the research that will make OTEC a reality.


VACUUM PUMP
SEA LEVEL
FILTER
DISCHARGE
WARM WATER TO TURBINE
COAST AND CONDENSE ZONE
~ 100 M
COLD WATER SHEET
MIST ACCEL ZONE
MIST GENERATOR
COLD WATER NOZZLE
WATER TURBINE
ELECTRIC GENERATOR
COLD WATER

PROJECTED CAPITAL COSTS OF A MIST LIFT OTEC POWER PLANT

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Marina del Rey, California

ABSTRACT

A conceptual design of a 4 MW Mist Lift OTEC power plant has been prepared. This design is based on a modest extrapolation of the mist transport data acquired in fresh water experiments in 1980-81 and ocean water experiments in 1983. It was optimized for minimum cold water use, with a condenser effectiveness of 0.9 yielding a gross output of 450 kW-sec/M^3 of cold water. Allowance for cold water pumping power, mist generator loss, filter loss, turbine efficiency, exit loss and noncondensible removal power reduce this yield to 300 kW-sec/M^3 of cold water.

The hull, composed of 3500 M^3 of reinforced concrete, has the general form of a buoy. Its maximum diameter is 26 meters, and the overall height is 95 meters, of which 80 meters are submerged. At the top, 15 meters above the ocean surface, is a platform that carries auxiliary equipment, the vacuum pump, and provides crew quarters. Preliminary estimates of the construction cost of a 4 MW power plant are in the range of $1500 to $2000 per kilowatt. The largest uncertainty is in the cost of the cold water pipe, which was assumed to be $3,000 per meter for a 4-meter-diameter pipe. The hull has been informally quoted at $650/kW.

Senator EVANS. Thank you very much. We will hold questions until we have heard from the rest of the panel. Mr. William Lang?

STATEMENT OF WILLIAM D. LANG, VICE CHAIRMAN, ENERGY COMMITTEE, INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS, INC.

Mr. LANG. Mr. Chairman, I appear before you today on behalf of the Energy Committee of the Institute of Electrical and Electronic Engineers.

The IEEE is the world's largest engineering society with approximately 250,000 members worldwide, 200,000 of which live and work in the United States.

Recently the House Science and Technology Committee approved legislation authorizing funding for Department of Energy research and development programs for fiscal year 1985. In so doing, the committee approved funding for solar, conservation, fusion, electric energy, and Energy Storage Systems Research Programs at levels higher than originally requested by the administration, approximately 7 percent over fiscal year 1984. We believe that the funding levels recommended by the House Science and Technology Committee are reasonable and urge similar action by this subcommittee.

Through testimony today, I would like to provide our Institute's perspective on the nature of the current United States' energy problems and steps we believe the Federal Government should be taking to alleviate the problems.

In our oral presentation, I would like to concentrate on two areas and leave the rest for the presentation.

Senator EVANS. We will include the entire statement in the record.

Mr. LANG. Thank you. We urge actions to increase the efficiency of energy use and to increase the diversity of energy sources.

With regard to energy efficiency, there are many examples where dollars spent on more effective energy use are more productive than investments in new capabilities. Much of the impetus for this came from the rapid and sudden increase in the cost of energy. Now, however, most of the gains from easy retrofits have been achieved. Further gains will require significant investment in higher efficiency technologies. Research can help this greatly.

With regard to the diversity of energy sources, the availability and costs of the various sources are so changeable and uncertain that the Nation's security demands a commitment to diversity. In the long run, that diversity must emphasize the renewable or nearly inexhaustible supplies. Solar and nuclear technologies have such long-term potential.

An abundant and secure supply of energy is essential to the well-being of our Nation. One way to measure a nation's energy efficiency is to examine the number of Btu's required to produce $1 of gross domestic product. In the relative stable period from the late 1940's until the 1960's, energy efficiency improved rather steadily—about 0.5 year—mostly as a result of improving technology.

Recently the rate of improvement has been increasing and achieved about 2 percent per year through the 1970's. Again, this has been caused primarily by the result of sharp rises in energy prices.

Analysts generally agree that U.S. energy consumption in the year 2000 of around 100 quads should provide for a healthy economy. The problem is that should increases in energy efficiency revert to the rate of the 1950's, early 1960's, a healthy gross national product will require much more than 100 quads of energy in the year 2000. The larger rates of energy efficiency increase must be maintained even though the easy fixes have been exhausted.

History tells us that market forces are not enough. Investments in energy-efficient technologies must be stimulated.

The Federal Government should support research activity to develop promising and undeveloped processes. Some examples of these opportunities are improved coal combustion techniques such as fluidized bed combustion, higher voltage electrical transmission for AC and DEC, higher burnup and/or lower enrichment light water reactor fuel, higher temperature combined cycle plants with and without cogeneration techniques.

In addition to the new technologies, Congress should seek ways to further encourage the improvement and the application of the existing technologies for energy efficiency. Examples include such things as power conditioning with speed control for motors, plasma arc smelting for ore reduction, heat pumps for waste heat recovery, and others.

Finally, the emerging conservation industry will well justify Government research support. Better ways to improve the efficiency of small but very numerous end uses of energy should be developed and made generally available. While not spectacular in individual application, such efforts in the aggregate will make a significant contribution to the Nation's energy resource.

In addition to increasing the energy efficiency of our economy, we must diversify the sources of energy on which we rely. It is important that such technology is available when the economic needs develop to avoid economic disruption.

Two specific technologies are as follows—solar technology is one. It has become clear that solar energy offers promise as a significant energy source on a permanent basis. Appropriate adoption of the various solar energy technologies can reduce energy costs and help the environment as well. Moreover, the United States can produce all of its solar energy production and services without the need for imports.

The technology also has potential for a substantial export market. The IEEE is convinced that the increased use of solar energy will make substantial contributions to the national interest.

Particular mention must be made of technologies which directly convert sunlight to electricity. Those need special attention. Current photovoltaic technologies are not generally economic but the rate of progress in improved efficiencies continues to meet or exceed the DOE projections. The present situation is that no company is willing to risk technological obsolesence by a commitment to a current technique. Federal research to the point of demonstrating commercial feasibility is needed to accelerate commercial photovoltaic power. Such a program will require moderate Federal expenditure, but past budget and proposed budget restriction in this area is not consistent with the timely development of this technology.

I would like to limit that to the oral testimony. We would be glad to answer any questions.

[The prepared statement of Mr. Lang follows:]

STATEMENT
BY
WILLIAM D. LANG
OF THE
INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS, INC.

BEFORE
SUBCOMMITTEE ON ENERGY RESEARCH AND DEVELOPMENT
OF THE
SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

APRIL 24, 1984

Mr. Chairman, members of the Subcommittee, my name is William D. Lang. I appear before you today with Dr. Charles Lawrence on behalf of the Energy Committee of the Institute of Electrical and Electronics Engineers (IEEE). The IEEE is the world's largest engineering society, with nearly 250,000 members worldwide, 200,000 of whom live and work in the United States.

Recently, the House Science and Technology Committee approved legislation authorizing funding for Department of Energy Research and Development programs for FY 1985. In so doing, the Committee approved funding for Solar, Conservation, Fusion, Electric Energy and Energy Storage Systems research programs at levels higher than originally requested by the Administration, but in no instance more than 7% over FY 1984 authorizations. We believe that the funding levels recommended by the House Science and Technology Committee are reasonable, and urge similar action by this Subcommittee.

Through our testimony today, we would like to provide our Institute's perspective on the nature of the current United States energy problems and steps we believe the Federal government should be taking towards alleviating the problems. We urge actions to increase the efficiency of our energy use and to increase the diversity of our energy sources. We believe that the free market can be constructively influenced by appropriate government policy and action.

With regard to energy efficiency, there have been many examples where dollars spent on more effective energy use are more productive than investments in new capabilities. Much of the impetus for this, of course, has been the sudden and rapid increases in the cost of energy. Now, however, most of the gains from easy retrofits have been achieved; further gains will require significant investments in higher efficiency technologies. Research can help this greatly, but the uncertainties of economic payoff are sufficient to generally preclude investments by commercial organizations. Such research can be justified, however, for the country as a whole.

With regard to the diversity of our energy sources, the availability and costs of the various sources are so changeable and uncertain that the nation's security demands a commitment to diversity. In the long-run, that diversity must emphasize renewable or nearly inexaustible supplies. Solar and fusion technologies have such long-term potential. Adequate Federal funding is essential to maintain the necessary scientific progress and to develop the necessary engineering designs for these technologies.

An abundant and secure supply of energy is essential to the well being of our nation. The government must set policy directions through investments in energy efficiency and in diversity of sources so that market forces will be guided towards both national security and healthy economic growth. The following provides more detail on these matters.

Increasing Energy Efficiency

One way to measure a nation's energy efficiency is to examine the number of BTU's required to produce one dollar of Gross Domestic Product. In the relatively stable period from the late 1940's to the mid 1960's, energy efficiency improved rather steadily at about .5% per year, mostly as a result of improving technology. Recently the rate of improvement has been increasing and achieved about 2% per year in the late 1970's. These large rates of improvement were the result of the sharp rises in energy prices which called attention to the many opportunities to improve energy efficiency rather easily. We are now, however, reaching the point where further gains are becoming more difficult and significant further gains will require improved technology. Only in this way can we avoid excessive energy requirements for our economy.

Analysts generally agree that a U.S. energy consumption in the year 2000 of around 100 quads should provide for a healthy economy. The problem is that should our increases in energy efficiency revert to the rate of the 1950's and early 1960's, a healthy GNP growth will require much more than 100 quads of energy in the year 2000. Thus, larger rates of energy efficiency increase must be maintained, even though the "easy fixes" have been exhausted. History tells us that market forces are not enough; investments in energy efficient technologies must be stimulated.

The Federal Government should support research efforts to develop promising, but undeveloped processes. Examples of such opportunities are:

1. Improved coal combustion techniques, such as Fluidized Bed Combustion.
2. Higher voltage electrical transmission, both Alternating Current and Direct Current.
3. Higher burn up and/or lower enrichment Light Water Reactor Fuel.
4. Higher temperature combined cycle plants, with and without cogeneration techniques.

In addition to new technologies, the Congress should seek ways to further encourage the improvement and the application of existing technology for energy efficiency. Examples include power conditioning with speed control for motors, plasma arc smelting for ore reduction, heat pumps for waste heat recovery, and microwave systems for surface drying and finishing treatments used in industrial processes. Congress can spur research to improve such technologies and encourage their application by appropriate financial incentives.

Finally, the emerging conservation industry well justifies some government research support. Better ways to improve the efficiency of small, but very numerous end uses of energy should be developed and made generally available. While not spectacular in individual applications, such efforts in the aggregate will make a significant contribution to the nation's energy future.

Diversify Energy Sources

In addition to increasing the energy efficiency of our economy, we must diversify the sources of energy on which we rely that we can reduce our reliance on depletable and imported resources. Along with the established industries there are important energy alternatives which require strong Federal research support. It is important that such technologies are available when the economic need develops to avoid economic disruptions. Two specific technologies for which we urge full Federal support are the following:

Solar Technology - It has become clear that solar energy offers promise as significant energy source on a permanent basis. Appropriate adoption of the various solar energy technologies can reduce energy costs and help the environment as well. Moreover, the United States can produce all of its solar energy products and services without need for imports. The technology also has potential for a substantial export market. The IEEE is convinced that the increased use of solar energy will make substantial contributions to the national interest. Solar energy is an emerging industry with needs that justify significant Federal involvement. The IEEE urges Federal Support for:

a. Research and development, including testing to demonstrate commercial feasibility.

b. Favorable regulatory policies.

c. Information dissemination and the development of standards.

d. Financial incentives to private investors in the areas of tax credits, loan assistance, etc.

Particular mention must be made of the technologies which directly convert sunlight to electricity, for these currently need special attention. Current photovoltaic technologies are not generally economic, but the rate of progress in improved efficiencies continues to meet or exceed DOE projections. The present situation is that no company is willing to risk technological obsolescence by a commitment to a current technique; Federal research to the point of demonstrating commercial feasibility is needed to accelerate commercial photovoltaic power. Such a program requires modest Federal expenditures, but past and proposed budget restrictions in this area are not consistent with the timely development of this technology. Also, inflexible restrictions which limit the Federal role to longer term research impedes the transition from the laboratory to commercial products.

Fusion Power - The fuel for fusion power is virtually inexhaustible and fusion must be considered as the most likely centralized power source for the future.

There are two aspects of fusion research, one is the development of a sound scientific base which includes both mainline and alternative fusion concepts. The other is to begin to move the technology into the engineering development phase. The IEEE urges sufficient funding to move forward in both of these areas.

The need for additional scientific research is to further enhance the understanding of fusion physics and to assure that alternatives to current mainline efforts having good potential receive adequate consideration. All engineering design requires a firm scientific base. Adequate work in this area is essential. In addition to scientific research, however, the fusion program has now reached the point where engineering issues must be addressed. Only in this way can the goal of a new energy source be achieved. The fusion program must include such an effort. The only vehicle available for this is the Tokamak Fusion Core Experiment as proposed by the fusion community. The IEEE endorses this program. It should not be considered as a substitute for scientific research, but an addition. Such a device is an essential step towards providing this promising new source of energy for our nation's future. *

In addition to the security of our energy supplies, the IEEE also has presented testimony elsewhere on some specific areas of DOE's research budget; research funding for electrical energy systems ** and supercomputer development. The electric energy systems program is concerned the developments and characteristics of large scale systems for electrical power transmission and distribution. It will require long lead times and continuity of funding through the whole R&D cycle to assure the larger and more efficient systems needed in the coming decades. It is essential that we adequately fund the applied research and development programs in large scale electrical systems so that they will be ready when needed.

Supercomputer development is another area of DOE's research budget that concerns the IEEE. In 1983 the USAB created a blue ribbon committee to address the topic of supercomputers; that committee's report (issued in October 1983) created a great deal of interest in the computer community and in the media. It has been quoted widely in news stories and magazine articles. A member of the

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[*] For a more detailed review of the DOE Fusion Program, reference testimony by Dr. Alan Mense on behalf of IEEE's Energy Committee before the House Science and Technology Committee's Subcommittee on Energy Research and Production, February 20, 1984.

[**] For a more detailed review of electric energy systems and energy storage program, reference testimony by Mr. William Feero on behalf of IEEE's Energy Committee before the House Science and Technology Committee's Subcommittee on Energy Research and Production, March 7, 1984.

committee presented the findings to the House Science and Technology Committee in hearings on November 15, 1983.

Because of the importance IEEE attaches to the need for accelerating research in supercomputer development and in improving access to these machines, we urge this committee to fund this program adequately. This funding, which comes under DOE's Basic Energy Sciences budget, would expand the applied mathematics computational research program and would provide a down payment, in effect, for the purchase of a supercomputer and associated network access equipment. OMB approved only $29,750,000 for DOE's supercomputer activities. We believe that additional funds would go far toward achieving some of the gains the U.S. needs to make in this very strategic technology.

IEEE's Scientific Supercomputer Committee found that the "economic and national security importance of supercomputers is far in excess of the number in use at this time". Each generation of mainline computer systems has descended from the technology of the previous generation of supercomputers. Without supercomputer leadership, U.S. computer vendors will soon be at a competitive disadvantage. Further, the frontiers of science and technology often yield only to the power of a supercomputer. These science frontiers include energy technologies. DOE's supercomputer development work may well prove crucial to the success of energy research programs being carried out by DOE.

IEEE recommended a Federal government expenditure of $100 million a year for five years to "...bring supercomputer development to a reasonable state-of-the-art level."

DOE's 1985 budget for supercomputers is an improvement over the amount provided in 1984 and the amount requested does include some new money ($6 million). It is imperative, however, that sufficient funds should be alloted at this time for the purchase of the next generation of U.S. supercomputers. These may become available as early as 1987 if funding is provided for their purchase now.

This concludes our formal statement, and I would be pleased to attempt to answer any further questions you might have.

Senator **Evans**. Thank you.

Next is J. Anderson, president of Sea Solar Power.

STATEMENT OF J. HILBERT ANDERSON, PRESIDENT, SEA SOLAR POWER, INC.

Mr. **Anderson**. I appreciate the opportunity to testify on this before the committee, on what we consider by far the most important source of energy on the face of the Earth, and that is commonly called OTEC. I felt it might be useful to provide here a short history of the development of ocean thermal energy conversion in the work of the Sea Solar Power, our own company.

In 1962, we became convinced that the development of ocean thermal power might be feasible. We studied the work of George Claude and analyzed the faults and difficulties that he encountered back in 1930.

Based on this, we started developing a design and recognized very early, as did George Claude, that the only way to make ocean thermal power really successful was to design floating plants. We presented our first paper on this subject in 1964.

In 1972 when the energy crunch started, the National Science Foundation became interested and we presented our ideas to them. Prior to that time, all of our work was virtually ignored because the public was told that nuclear power would become too cheap to meter.

When the National Science Foundation and later ERDA started looking at the possibilities, they decided that since we were proponents of the development of this vast and unlimited energy source, we were not qualified to pass judgment on it. Therefore, they gave large contracts to several of the large aerospace companies for evaluation of the concept.

The aerospace companies elected to try to develop their own designs of ocean thermal powerplants and used many concepts that we had discarded years before. As a result, they came up with feasibility studies which said that yes indeed, ocean thermal power is technically feasible, but their designs showed that floating plants of reasonable capacity would weigh up to 250,000 or 300,000 tons.

Since then, many DOD-supported studies based most of their findings on these so-called baseline plants. It seems obvious that since an ocean thermal powerplant uses no fuel, then the capital cost of the plant is the major cost involved in producing power. The sheer weight and size of these plants soon proved that although ocean thermal power could be technically feasible, it certainly could not be economically feasible with their proposed designs.

Congress tried to promote and hasten the development of ocean thermal power and provided funds for actual design studies of modest size powerplants. Unfortunately, these appropriations were provided to companies which proposed shelf-mounted plants. These plants would not fulfill the objective of what is really needed, namely, floating plants in the ocean.

Since then they also found, as had been reported earlier to DOE, that shelf-mounted plants merely compound the difficulties of both floating plants and land-based plants. As a result of this, the appropriations for ocean thermal power have steadily decreased and perhaps properly so.

In the meantime, Sea Solar Power has continued innovative design developments which permitted us to decrease the size and cost of the plants. Today we can confidently predict that a 100 megawatt powerplant will weigh not more than 25,000 tons. Such a plant is similar in size and construction to a floating oil well drilling rig, of which there are hundreds in operation throughout the world. For this reason, we can also confidently predict what the cost of such a plant will be.

In 1964, we predicted the cost of an ocean thermal plant would be $166 per kilowatt. At that time, the first large commercial nuclear plant, namely, the Oyster Creek plant, was built for $125 per kilowatt.

Today, we can confidently predict that a 100 megawatt ocean thermal plant of Sea Solar Power design will weigh 25,000 tons and will cost appproximately $100 million, or $1,000 per kilowatt. At a capacity factor of 90 percent, this means that the actual cost per kilowatt generated 100 percent of the time would be $1,111 per kilowatt. Nuclear powerplants are now predicted to cost $2,500 per kilowatt.

In recent estimates made for the Electric Power Research Institute, based on a capacity factor of 55 percent, then the cost of a nuclear plant would be $4545 per kilowatt, supplying power 100 percent of the time. As I am sure you are aware, there are a number of nuclear powerplants that are now being built that will actually cost up to 4,000 per kilowatt. Some of them have been stopped before being built because of the high cost.

Enough research and development work has been done by various people to show that ocean thermal power is indeed technically feasible. The Sea Solar Power design can make this economically practical. In fact, it will undoubtedly provide the lowest cost power on the face of the Earth that is in unlimited supply.

While we keep on dillydallying with inferior designs, other countries are moving ahead and becoming more and more enthusiastic about the development of ocean thermal power. For example, Japan now has several plants, although small, in experimental operation.

Shall the United States take a back seat in the development of what is unquestionably the world's largest and most important source of energy and that can promote good will and a higher standard of living to most of the world?

[The prepared statement of Mr. Anderson follows:]

SEA
SOLAR
POWER

Power from the Sun via the Sea
2422 S QUEEN STREET, YORK, PA. 17402 (717) 741-0884

Testimony Before Senate Subcommittee On
Energy Research And Development

April 24, 1984

It may be useful to provide here a short history of the development of Ocean Thermal Energy Conversion in the work of Sea Solar Power, Inc.

In 1962, we became convinced that the development of ocean thermal power might be feasible. We studied the work of George Claude and analyzed the faults and difficulties that he encountered back in 1930. Based on this, we started developing a design, and recognized very early, as did George Claude, that the only way to make ocean thermal power really successful was to design floating plants. We presented our first paper on this subject in 1964. In about 1972 when the energy crunch started, the National Science Foundation became interested and we presented our ideas to them. Prior to that time all of our work was virtually ignored because the public was told that nuclear power would become too cheap to meter.

When the National Science Foundation and later ERDA started looking at the possibilities, they decided that since we were proponents of the development of this vast and unlimited energy source, we were not qualified to pass judgement on it. Therefore, they gave large contracts to several of the large aerospace companies for evaluation of the concept.

The aerospace companies elected to try to develop their own designs of ocean thermal power plants, and used many concepts that we had discarded years before. As a result they came up with feasibility studies which said that yes indeed, ocean thermal power is technically feasible, but their designs showed that floating plants of reasonable capacity would weigh up to 250,000 or 300,000 tons. Since then, many DOE supported studies based most of their findings on these so called base line plants. It seems obvious that since an ocean thermal power plant uses no fuel, then the capital cost of the plant is the major cost involved in producing power. The sheer weight and size of these plants soon proved that although ocean thermal power could be technically feasible, it certainly could not be economically feasible with their proposed designs.

Congress tried to promote and hasten the development of ocean thermal power, and provided funds for actual design studies of modest size power plants. Unfortunately, these appropriations were provided to companies which proposed shelf-mounted plants. These plants would not fulfill the objective of what is really needed, namely floating plants in the ocean. Since then they also found, as had been reported earlier to DOE, that shelf-mounted plants merely compounded the difficulties of both floating plants and land based plants. As a result of this, the appropriations for ocean thermal power have steadily decreased, and perhaps properly so.

In the meantime, Sea Solar Power has continued innovative design developments which permitted us to decrease the size and cost of the plants. Today, we can confidently predict that a 100 Mwe power plant will weigh not more than 25,000 tons. Such a plant is similar in size and construction to a floating oil well drilling rig, of which there are hundreds in operation throughout the world. For this reason, we can also confidently predict what the cost of such a plant will be.

In 1964, we predicted the cost of an ocean thermal plant would be $166/kw. At that time, the first large commercial nuclear plant, namely the Oyster Creek plant, was built for $125/kw.

Today, we can confidently predict that a 100 Mwe ocean thermal plant of Sea Solar Power design will weigh 25,000 tons and will cost approximately $100 million or $1000/kw. At a capacity factor of 90%, this means that the actual cost per kilowatt generated 100% of the time would be $1111/kw. Nuclear power plants are now predicted to cost $2500/kw, in recent estimates made for the Electric Power Research Institute. Based on a capacity factor of 55%, then the cost of a nuclear plant would be $4545/kw supplying power 100% of the time. As I am sure you are aware, there are a number of nuclear power plants now being built that will actually cost up to $4000/kw. Some of them have been stopped before being built because of the high cost.

Enough research and development work has been done by various people to show that ocean thermal power is indeed technically feasible. The Sea Solar Power design can make this economically practical. In fact, it will undoubtedly provide the lowest cost power on the face of the earth that is in unlimited supply

While we keep on dillydallying with inferior designs other countries are moving ahead, and becoming more and more enthusiastic about the development of ocean thermal power. For example, Japan now has several plants, although small, in experimental operation.

Shall the United States take a back seat in the development of what is unquestionably the world's largest and most important source of energy, and that can promote good will and a higher standard of living to most of the world?

Respectfully submitted,

Anderson

J. Hilbert Anderson
President
SEA SOLAR POWER, INC.

Senator EVANS. Thank you very much. The last on the panel is Dr. Lloyd Lawrence. You go ahead, Dr. Lawrence.

STATEMENT OF DR. LLOYD R. LAWRENCE, JR., DIRECTOR, TECHNICAL DEVELOPMENT, MECHANICAL TECHNOLOGY, INC.

Dr. LAWRENCE. Thank you, Mr. Chairman. I am Bob Lawrence, director, technical development, of MTI, which is a high technology corporation of about 900 people located in northern New York with other plants around the country. We are about half product and half research and development at MTI.

As another brief introduction, Mr. Chairman, I have spent about 8 years of my life as an executive in the Federal Government followed by 2 years as an executive in the gas industry and now 5 years with the high technology corporation.

From that perspective, I have written a brief background to my testimony. By the way, if possible, I would like the testimony included in its entirety for the record and I will just discuss briefly some of the key elements.

Senator EVANS. The testimony will be included in its entirety.

Dr. LAWRENCE. Thank you, Mr. Chairman. I would like to turn if we could to page 3 of the testimony which is a series of figures. I know that you mentioned early on that, the tough decision as to where to put our Federal dollars for the maximum national benefit that you gentlemen are going through down here. It is certainly an excruciatingly difficult process.

I think that the four figures on page 3 can point out something that I think needs to be included in this process. I am sure it probably is, but if we could review this briefly, you will notice that the top line it has the balance-in-trade deficit which is the cash flow out of this country due to, of course, the rest of the world outselling us in the international marketplace. Since 1975, that deficit total now is $327.5 billion, which it is very clear if we just had a balance of trade that was even, those monies would be in our economy flowing amongst our own employees and providing tax revenues.

If we move down one to the current account, this is the reason that the financial community has said up until 1982 that the balance of trade really didn't matter because we were selling enough insurance and financial services, things like that, overseas that the cash-flow still remained about even, but as you can see, this balance of trade deficit in 1982 caught up with us, and even the current account became negative, and if you read Newsweek magazine of February 28 of this year, there is an article that points out that in 1984, the United States will become an international net debtor for the first time since 1917.

Moving along to the next item which is what you gentlemen are spending a lot of time on now, the budget deficit, I think it is the feeling of a number of people that the budget deficit directly reflects what is going on in international trade in the current account. If we don't have the money flowing in our economy, our own funds, it is tough to get revenues from it, it is tough to balance the budget, and on the bottom you will see the net effect of the above three which is the cumulative inflow of foreign funds to the United States which you see now is up to $225 billion, the end of 1983, and looking at the fact that Getty Oil was purchased for $10 billion can show you rather dramatically how much of this Nation's former assets are now owned by foreign interests.

What this leads to, Mr. Chairman, in my mind is that where the Nation's dollars are best spent is to enhance those areas of our economy which are productive, that can produce goods and services that are competitive, that can be sold overseas, and strengthen our economy through getting the cash-flow back into this country.

One other thing that is worthwhile to note is at the end of World War II, our total national debt actually exceeded our gross national product, but our economy recovered from that, and the way it recovered was by the international sale of durable goods, bringing the cash back to this country, strengthening our economy.

Well, this then leads to the conclusion in the background on page 5 which says, "It is clear, then, that an investment which enhances our national capability to produce goods has the greatest economic benefit of any investment. It is also clear that a reduction in our balance-of-trade deficit will produce positive cash-flow back to the United States, helping employment and our national economic health. It is also abundantly clear that the largest element of our trade deficit continues to be foreign oil. Therefore, an investment with the highest national benefit attached would appear to be an investment in the goods-producing sector which would enhance our national competitiveness * * *" international competitiveness actually, " * * * and reduce our dependence on foreign oil. It is this kind of investment which is routinely made by the conservation technology programs * * *" within the Department of Energy, and it is for that reason, Mr. Chairman, that on page 1 we make the recommendations that we do for the energy conservation programs, especially the technology programs within DOE.

If I may turn now briefly to a subject on which we have a vested interest, MIT is a prime contractor on something called the Automotive Stirling Engine Program. It has a long history of support from this subcommittee. Senator Domenici has followed this since the early 1970's when the Jet Propulsion Lab did a major study on what were the most viable engine concepts for the future of our Nation in terms of multifuel use, high efficiency, environmental acceptability, and consumer acceptability.

We were fortunate enough in 1978 to win the automotive Stirling engine contract which is really in some of its final phases now. Last year, the Congress appropriated money for us to begin the Mod 2 Program which was the final engine that incorporates all of the technology paid for to date under the program, incorporates it into an engine which we feel will meet all the goals of the legislation and of the contract. We are proceeding with that. We have ordered the long lead items and the funds which we are requesting for fiscal 1985 will complete the purchase of all of the mechanical parts needed for this program.

Our request for fiscal 1986, 1987 will be substantially less as we move to complete the contract and the goals that were originally established. I would like to submit for the record at this time, Mr. Chairman, a letter signed by the Director of the NASA Lewis Laboratory, Dr. Stofan.

[The letter from Dr. Stofan follows:]

National Aeronautics and
Space Administration

Lewis Research Center
Cleveland, Ohio
44135

NASA

FEB 23 1984

Reply to Attn of: 4100

Mechanical Technology Incorporated
Attn: Mr. Bruce Goldwater
General Manager
Stirling Engine Systems Division
968 Albany-Shaker Road
Latham, NY 12110

Subject: Semiannual Evaluation of Contractor Performance on Contract DEN 3-32 Automotive Stirling Engine

In accordance with Article XVII, "Award Fee Evaluation and Determination Procedure," and Article XVIII, "Award Fee Performance Criteria," of the subject contract, an evaluation of Mechanical Technology Incorporated's performance under that contract for the period July 15, 1983, to January 14, 1984, has been completed. The results of this evaluation, based upon the stipulated criteria, are submitted herein:

A. Effective Program Management

MTI's performance in this category is rated outstanding.

NASA is very pleased with your outstanding management of the Automotive Stirling Engine Program. The program continues to be a smooth-running, well-coordinated, highly productive program. Key milestones are being met and costs are being very well controlled.

Also on the positive side, we are happy to note your continuing efforts on, and improvement in the timeliness of, publishing program reports. These have achieved a high level of excellence both in content and timeliness.

Your cooperation and working arrangements with NASA are most gratifying. Your efforts in replanning the program to include a MOD II engine development and in developing strategies to accommodate funding shortfalls are appreciated.

B. Effectiveness of Technical Approaches

Your performance rating in this criterion is outstanding.

The factors considered in evaluating this criterion are:

1. MTI's excellent approach to proof-of-concept technology development. By assuring that components and systems are

thoroughly tested in rigs before being evaluated on an engine, you are proceeding in both a cost-effective as well as a technically sound manner.

2. Your very effective use of MOD I, MOD IA, and P-40 engines to investigate seal, performance, and durability problems.

3. Verifying and quantifying the effect of crosshead clearance on seal life.

4. The development of a technique to use the grain microstructure of the heater tubes to provide a "photograph" of the temperature history of the material. This has proven to be a valuable development diagnostic tool.

5. Your sound approach to investigating the performance shortfall in the MOD IA engine. By doing a careful analysis of the data, combined with computer modeling, you were able to plan tests to quickly eliminate variables.

Although the primary program goal is efficiency (MPG), the efficiency gain must be achieved in a configuration that has the potential to be cost competitive. I encourage you to continue your performance vs. cost trade-off studies and to continue to explore means to get additional industry manufacturing experience into the program.

C. Accomplishment of Work Plan Objectives

Rating: Outstanding

We are pleased by your continuing high marks in this criterion. You have met major program milestones on or ahead of schedule despite funding uncertainties and shortfalls.

Completing the 1000-hour endurance test on a MOD I engine as planned was a significant accomplishment. This is a major first step in verifying the durability of the engine configuration. We also note your work with the transient test vehicle with mileage and emissions right on target for this point in the program. The development of analytical techniques to predict in-vehicle mileage and emissions based on steady state dynamometer data is another step forward.

Your effort in support of the Industry Test and Evaluation Program is also noted. Completion of the engine and test vehicle for GM Research, on schedule, is very important to the Government's program.

We feel that even with the high rating given, there still is some room for improvements -- that is in the timeliness of test plan submittals. I think you will agree that sufficient lead time must be provided in order to allow a proper review. We encourage you to continue to pay attention to this important detail.

D. Effective Technology Transfer

MTI's rating in this criterion is outstanding.

You have done an excellent job of transferring foreign technology to MTI. This is evidenced by the recent design and analysis of the V-4 engine configuration; the assembly, test and repair of experimental engines; and the advanced component development all being done at MTI.

You have tried to keep industry informed on the status of technology development by frequent and quality presentations at technical conferences. We encourage you to continue.

As in the past, we urge you to continue to explore ways to broaden the involvement of U.S. industry. Your support of Valmont Industries in their commercialization attempt is a good example.

In summary, we rate your performance for this six-month period outstanding. We are very pleased to have you as a part of the NASA team. I welcome any comments you may have concerning our evaluation.

Andrew J. Stofan
Director

cc:
NASA Hdq/P. R. Miller
NASA Hdq/J. F. Slomski
DOE/A. A. Chesnes
DOE/R. T. Alpaugh
DOE/P. L. Sutton

Dr. Lawrence. We get evaluated by NASA. On this program NASA is the program manager for the Department of Energy. We get evaluated by them every 6 months on how effectively we are conducting the program. We are rated in four different categories—management, technical approach, accomplishment of work plan objectives, and technology transfer.

This letter dated February 3, 1984, has us as outstanding, the highest possible rating, in every single category. It is three pages describing why the program is rated that way, and I would like to submit this for the record at this time.

That summarizes my testimony. Thank you very much, Mr. Chairman.

[The prepared statement of Dr. Lawrence follows:]

Testimony of
Dr. L. R. Lawrence, Jr.

Mechanical Technology Incorporated
Latham, New York

Subcommittee on Energy Research and Development
Committee on Energy and Natural Resources

Hearings on DOE Conservation Program

March 16, 1984

Mr. Chairman and members of the Committee: I am Dr. L. R. Lawrence, Jr., and I am Director for Technical Development of Mechanical Technology Incorporated (MTI). I appreciate the opportunity to come before you today to discuss the relationship between the DOE Conservation Technology programs and the nation's needs in the areas of trade, energy, and productivity. As you know, Mr. Chairman, MTI is a high-technology organization, dedicated to evolving products in the residential, commercial, and industrial sectors from our strong technology core. We are one of the medium-size (900 people), aggressive companies responsible for a large part of the "industrial innovation" which occurs in this nation. We have been successful in commercializing our innovations to a significant extent, and we are most appreciative for the partnership we have had with the federal government in addressing those areas of high risk and high potential which fall outside the normal corporate investment criteria.

My testimony today will address, broadly, the national economic situation and the major positive role to be played by a well-funded and managed DOE conservation technology program. Specifically, I recommend the following:

1. In the DOE Transportation program, $17.5 million for the highly successful Automotive Stirling Engine (ASE) program. These funds will allow the continuation of the congressionally mandated MOD II program with the purchase and development of all needed MOD II hardware. Of the $17.5 million, $14 million would be allocated to the prime contract.

2. In the Industrial Conservation program:

Waste Energy Reduction	$14.0 M
Industrial Process Efficiency	14.0
Industrial Cogeneration	5.0
Implementation and Deployment	4.0
Program Direction	3.0
Thin Strip Casting	7.0
Advanced Steel Plant Study	1.0
TOTAL	$48.0 M

3. In the Buildings program, $7 million for gas heat pumps to accelerate the development efforts on promising longer-term prototypes.

Background

I would like to begin my testimony by examining Figures 1 and 2 in parallel. It is intriguing to see the trends over the last few years in Merchandise Trade, and the cost of foreign oil when compared to the current account and the federal budget deficit. In addition, the total foreign investment in the U.S. over the past 10 years exceeds $225 billion. This shows a strong degree of foreign control over our economy which would not be present if the balance of trade had been maintained at even or had been positive. In fact, since 1975, over $327.5 billion dollars have left the control of the United States economy and have come under foreign control through balance of trade deficits. Imagine the positive effect on our employment and federal revenue situation if those funds had remained and were circulating in the United States economy, under United States control.

Until the end of 1981, the balance of trade deficit was rationalized to be inconsequential since the current account (total cash flow in and out of the United States) remained even, or slightly positive. The increase in foreign sale of services (insurance, finance, etc.) when coupled with foreign investment in the United States continued to maintain a cash flow balance at the United States border. However, in 1982 and 1983, even this measure turned sharply negative, showing a strong trend of increasing cash flow out of the United States. This, again, results in overall negative effects on our economy in terms of jobs, revenues, and our projected capability to maintain our national lifestyle.

Turning from these numbers, for a minute, it is worthwhile to note that at the end of World War II, our total national debt equalled our Gross National Product. We recovered from that situation by producing and selling goods, worldwide, with a substantial yearly surplus in merchandise trade. Much of this cash inflow came from producing and selling steel to the other industrialized nations whose industries had been destroyed by the war. Steel and steel-based products, such as vehicles and farm equipment, made up a major portion of overseas sales. Our competition was negligible, and our economy strengthened and prospered from a national cash inflow due to the overseas sale of United States manufactured goods. The rest of the industrialized world learned from this experience; it learned that the maintenance and growth of a strong economy is overwhelmingly dependent upon having a positive balance of trade and a positive current account. We have forgotten our own lesson!

After this brief discussion of the need for a positive balance of trade for national economic health, let us now turn to the nation's employment distribution as a function of manufacturing. In its Monthly Labor Review, December 1983, the Department of Labor shows the nation's employment breakout in the goods-producing (manufacturing, mining, construction) and service-producing (transportation, public utilities, wholesale and retail trade, finance, insurance, real estate, other services) sectors. In 1981, 25,497,000 people were employed in the goods-producing sectors of which 20,170,000 were in manufacturing. In 1982, this number dropped to 23,907,000 as manufacturing dropped to 18,853,000 (mining and construction changed only slightly). In October of 1983, the goods-producing sector had recovered slightly to 24,167,000 as manufacturing recovered slightly to 19,040,000; two million people below the record of 21,040,000 employed in manufacturing in 1979 and 26,461,000 employed in the goods-producing sectors in the same year. In the area of services, employment

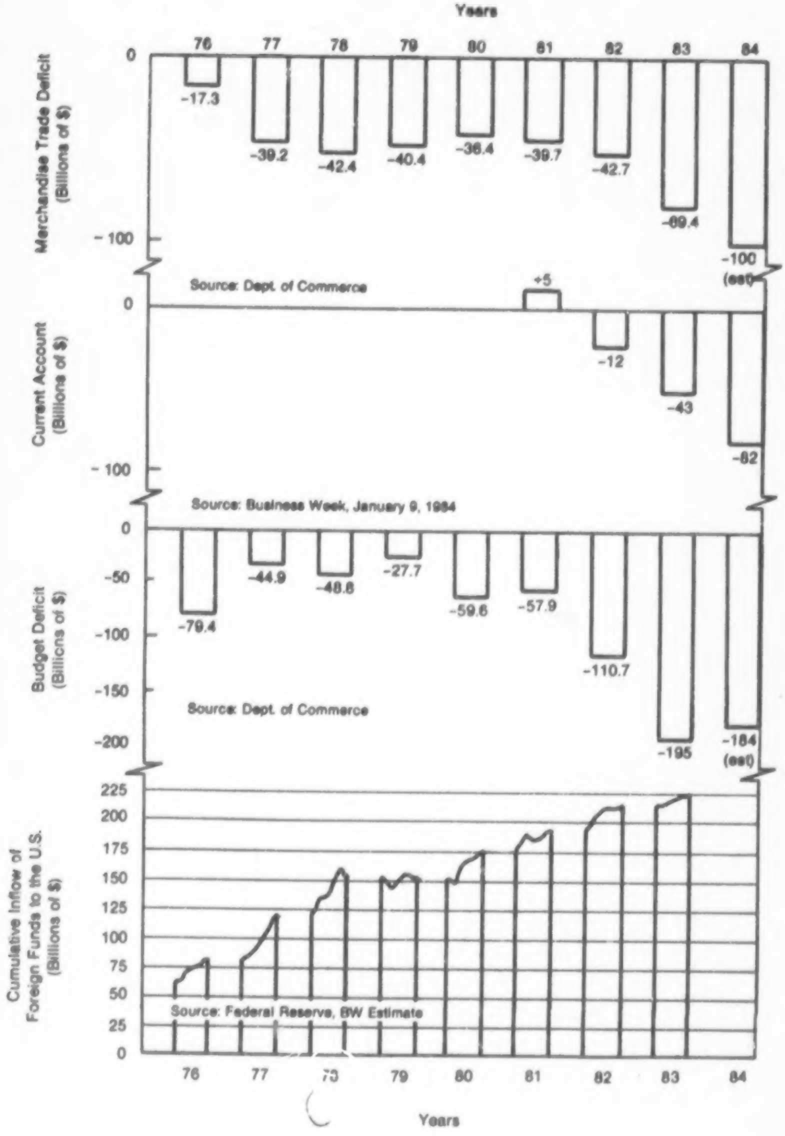
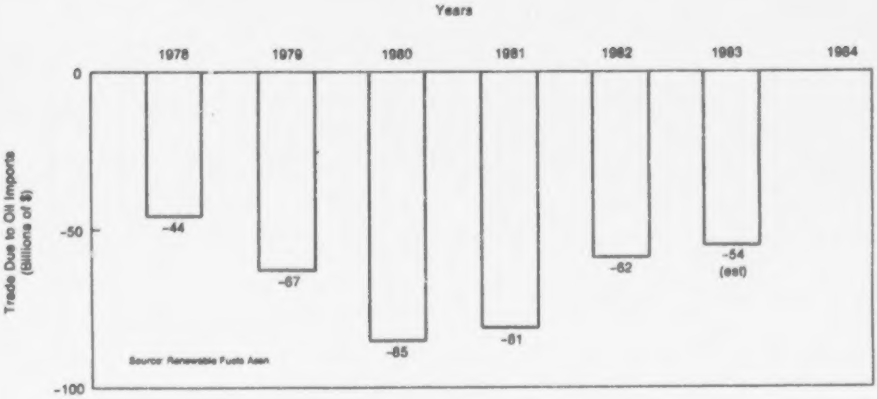

Years
76
77
78
79
80
81
82
83
84
Merchandise Trade Deficit (Billions of $)
0
-100
-17.3
-39.2
-42.4
-40.4
-36.4
-39.7
-42.7
-69.4
-100 (est)
Source: Dept. of Commerce
Current Account (Billions of $)
0
-100
+5
-12
-43
-82
Source: Business Week, January 9, 1984
Budget Deficit (Billions of $)
0
-50
-100
-150
-200
-79.4
-44.9
-48.8
-27.7
-59.6
-57.9
-110.7
-195
-184 (est)
Source: Dept. of Commerce
Cumulative Inflow of Foreign Funds to the U.S. (Billions of $)
225
200
175
150
125
100
75
50
25
0
Source: Federal Reserve, BW Estimate
76
77
78
79
80
81
82
83
84
Years

Figure 1



Source: Renewable Fuels Assn

Figure 2

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increased slightly from 65,660,000 in 1981 to 65,690,000 in 1982, and 66,900,000 as of October 1983.

Now let us take a brief, simplistic look at the overall national benefit of an increase in manufacturing, an increase in services, and (for added emphasis) an increase in defense production.

When a product is produced, it requires a building, tools or machinery, and employees to produce it. That's just the beginning. It also requires wholesale/retail trade, financing, insurance, transportation, and other services. In other words, a growth in produced goods automatically creates growth in service employment as well. Therefore, a manufactured product has a large economic multiple associated with it!

A service, by definition, services something. A growth in service employment means, simply, that additional things are being serviced. It makes no distinction between foreign or domestic items, and it creates no perceptible additional employment outside of its own sector. It has a low economic multiple asociated with it.

It is widely known that an investment in defense, although often required for basic national survival, is an investment with a low economic multiple. A defense item is generally either parked, stored, practiced with, or destroyed, and does not circulate in the economy. Although it may need to be transported or financed, it does not require wholesale or retail trades, nor is liability insurance required. Product liability is not a military concern. Military sales to overseas entities can help the balance of trade, but the economic multiple is clearly not competitive with a manufactured item for commercial sale and use.

It is clear, then, that an investment which enhances our national capability to produce goods has the greatest economic benefit of any investment. It is also clear that a reduction in our balance-of-trade deficit will produce positive cash flow back to the United States, helping employment and our national economic health. It is also abundantly clear that the largest element of our trade deficit continues to be foreign oil. Therefore, an investment with the highest national benefit attached would appear to be an investment in the goods-producing sector which would enhance our national competitiveness and reduce our dependence on foreign oil! It is this kind of investment which is routinely made by the conservation technology programs within DOE.

The Automotive Stirling Engine (ASE) Program ($17.5 M)

During the past few years, DOE complied with the urgings of OMB and consistently submitted the ASE program to the Congress at zero. Equally consistently, the Congress restored this program to meaningful funding levels, allowing substantial success to occur. We wish to express our gratitude and congratulations to this and the other Congressional Subcommittees who have continually supported us and made this kind of success possible. Thanks to the foresight of Congress, the U.S. now has the premier Stirling engine team in the world, with a variety of product prototypes under development, all with the inherent characteristics of high efficiency, low noise, multifuel capability, and environmental acceptability. For the last two years, the ASE program has been evaluated every six months by NASA, who manages the program for DOE, and for these last two years, the program has been rated "outstanding" in all technical and managerial categories.

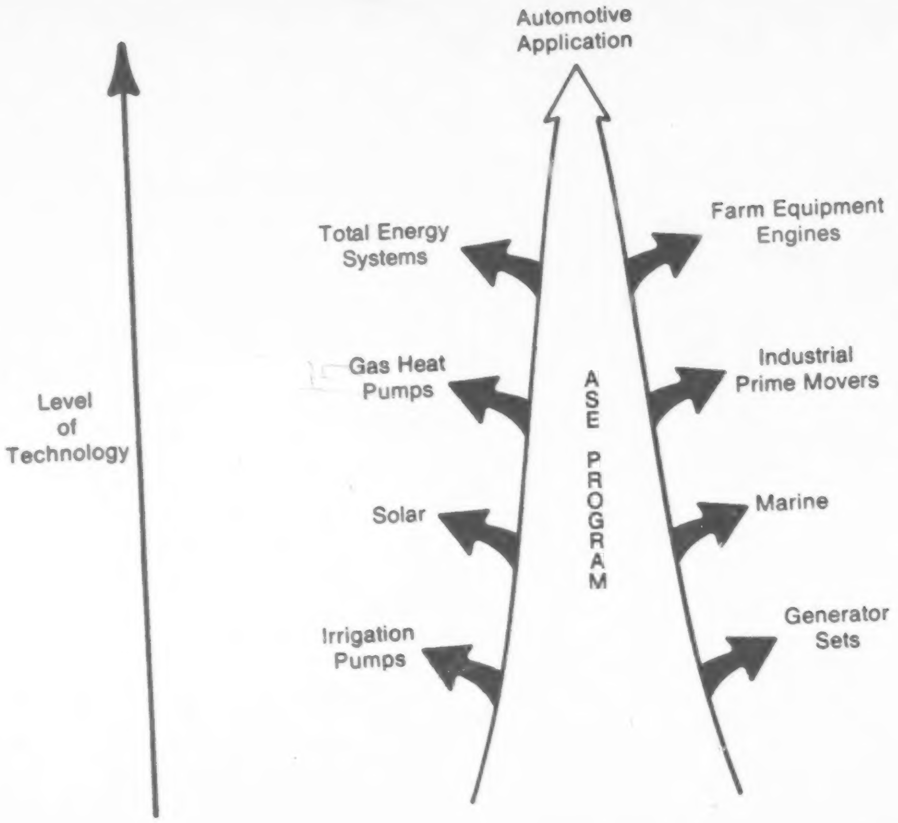
Level
of
Technology
Automotive
Application
ASE PROGRAM
Total Energy
Systems
Gas Heat
Pumps
Solar
Irrigation
Pumps
Farm Equipment
Engines
Industrial
Prime Movers
Marine
Generator
Sets

Fig. 3 Spin-Off Applications from Automotive Stirling Technology

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After 5-1/2 years of operation, the program remains on schedule, within budget, and meeting or exceeding its technical goals.

The ASE program has a number of specific objectives stemming from Public Law 95-238. These are:

- A 30% improvement in fuel economy over a comparable production engine
- Operation within projected 1985 emissions standards ($NO_x < 0.4$, HC < 0.41, CO < 3.4 grams/mile, and particulates < 0.2 gram/mile)
- Interchangeable operation on a variety of liquid fuels
- Reliability and life expectancy comparable to commercial engines
- Initial cost and life-cycle cost competitive with conventional engines
- Acceleration suitable for safety and consumer considerations
- Noise and safety characteristics meeting the 1984 Federal Standards

To achieve national acceptance, the automotive Stirling engine must be capable of being packaged in a small compartment, be able to provide sufficient power to propel a weighty vehicle, and still meet exacting performance criteria, such as acceleration from 0 to 60 mph in 15 seconds. The engine must be efficient over a wide range of power and speed settings, providing high fuel economy both in the stop-and-go environment of city driving and in the constant-speed cruising of highway driving. It must not pollute, and it must be capable of using (in the future) alternative fuels. It must be inexpensive to manufacture and capable of being serviced (routine maintenance) by the general public. Finally, a Stirling vehicle must be capable of operation in hot and cold climates while providing the "operator" with a "cabin" environment that is comfortable in terms of temperature, humidity, noise, and vibration.

Although the time frame and magnitude of the ASE program have been altered by budget restrictions over the past three years, the conceptual design of the Mod II was completed in 1983 at the recommendation of this subcommittee; further, it was the Congress's mandate that the FY84 program include the design and hardware procurement for Mod II engines. In order to meet the legislated goals in a timely fashion, all remaining Mod II engine hardware will be manufactured and preassembled in FY85 for full engine system test and evaluation in FY86. Hence, our request for a FY85 appropriation is $17.5 million, of which $14 million is expected to be allocated directly to the MTI contract.

Providing the United States with this technology will place it in the forefront of leadership in other Stirling applications. Efforts in Stirling engine development are already being conducted elsewhere in this country, as well as in foreign countries; Figure 4 is a summary of these activities. Immediately spinning off from MTI's ASE program is the Industry Test and Evaluation Program (ITEP) with General Motors, John Deere, and Cummins. Within the United States, the application of Stirling engine power to agricultural irrigation and solar energy generation is well in place and in the process of being commercialized. Further, the advantages of applying Stirling engines in space is only now being realized. And, lastly, the use of Stirling engines in generator sets is being evaluated by the military due to the engine's inherent low exhaust temperature and noise level, as well as its multifuel capability. However, foreign activity at Toyota (Japan) and Daimler-Benz (Germany) is also known to be occurring in the automotive field. At Daimler-Benz, for example, a light-duty van is being used to evaluate different engine systems. Also beyond the U.S., India is known to be assessing the Stirling engine for the automotive applications, and China

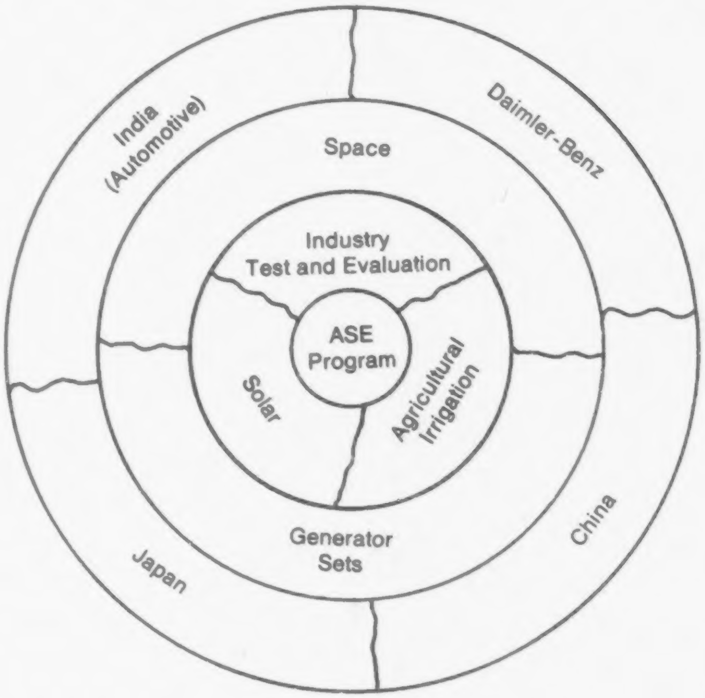
India
(Automotive)
Daimler-Benz
Space
Industry
Test and Evaluation
ASE
Program
Solar
Agricultural
Irrigation
Generator
Sets
Japan
China

Fig. 4 Activities of Interest Surrounding the ASE Program

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is evaluating it for a variety of applications (due mainly to its multifuel capability).

These developments underscore the vast potential for jobs and for technological expansion offered by the Stirling engine. Through the introduction of Stirling technology into U.S. products, new jobs in manufacturing and services, as well as an increase in associated trade employment, will result. The multifuel capability of the Stirling engine will provide personal and national security in times of petroleum dislocation, and the Stirling engine will meet the emission standards defined by the Clean Air Act, thereby contributing to the national effort to upgrade our environment. The ASE also provides an advantage to improving our noise environment, as the noise level emitted from a Stirling engine is much less than that of a conventional engine -- the Mod I vehicle installation did not require a muffler because of the extremely low level of noise in the exhaust. Finally, the overall potential for conserving valuable fuel resources through the use of more efficient Stirling engines in automobiles and in other applications is immense. This potential has been clearly shown through results already published from the ASE program.

Due to the foresight of congressional subcommittees, the ITEP was initiated in 1983. ITEP is directed at providing engines to industry so that U.S. companies can evaluate and assess the applicability of Stirling engines. General Motors, John Deere, and Cummins all signed formal agreements with NASA-Lewis to participate in this evaluation. The first ITEP engine was tested successfully and installed in a vehicle, which is currently being passed through a series of check-out tests, is on schedule, and is being delivered to General Motors this month. This vehicle will undergo chassis dynamometer tests, cooling tunnel tests, and road driveability tests, all conducted by General Motors' engineers and technicians at their own site and at their own expense. A second engine is being prepared for assembly and will be delivered to the John Deere Company in July 1984, at which time the engine will be tested and evaluated in a test cell. Cummins' role in ITEP will be to keep abreast of the tests conducted at both sites, evaluate data, and when appropriate, participate in engine teardowns to inspect the condition of selected components.

No disagreement exists regarding the fact that implementing a new engine technology, such as Stirling, into the automotive industry is extremely difficult. To recognize this difficulty requires the understanding of the implementation process: it begins at the research level with technical people agreeing on the potential of the technology, and progresses through a demonstration phase, an experimental phase, a prototype phase, a preproduction phase and, finally, to production.

Figure 5 shows that the technical community began to take an active interest in Stirling engines once the Mod I data was released, and it is anticipated that the Mod II data will lead to a consensus of opinion, within the same community, that the full potential of the Stirling engine can be realized.

The Industrial Conservation Program ($48.0 M)

Mr. Chairman, industry and government in this country have traditionally been adversaries, especially in those sectors providing commercial goods. In all government, there is only one entity which I know that has overcome this stigma to the point where it is a trusted and respected industrial companion. This entity is the Office of Industrial Conservation in the Department of Energy.

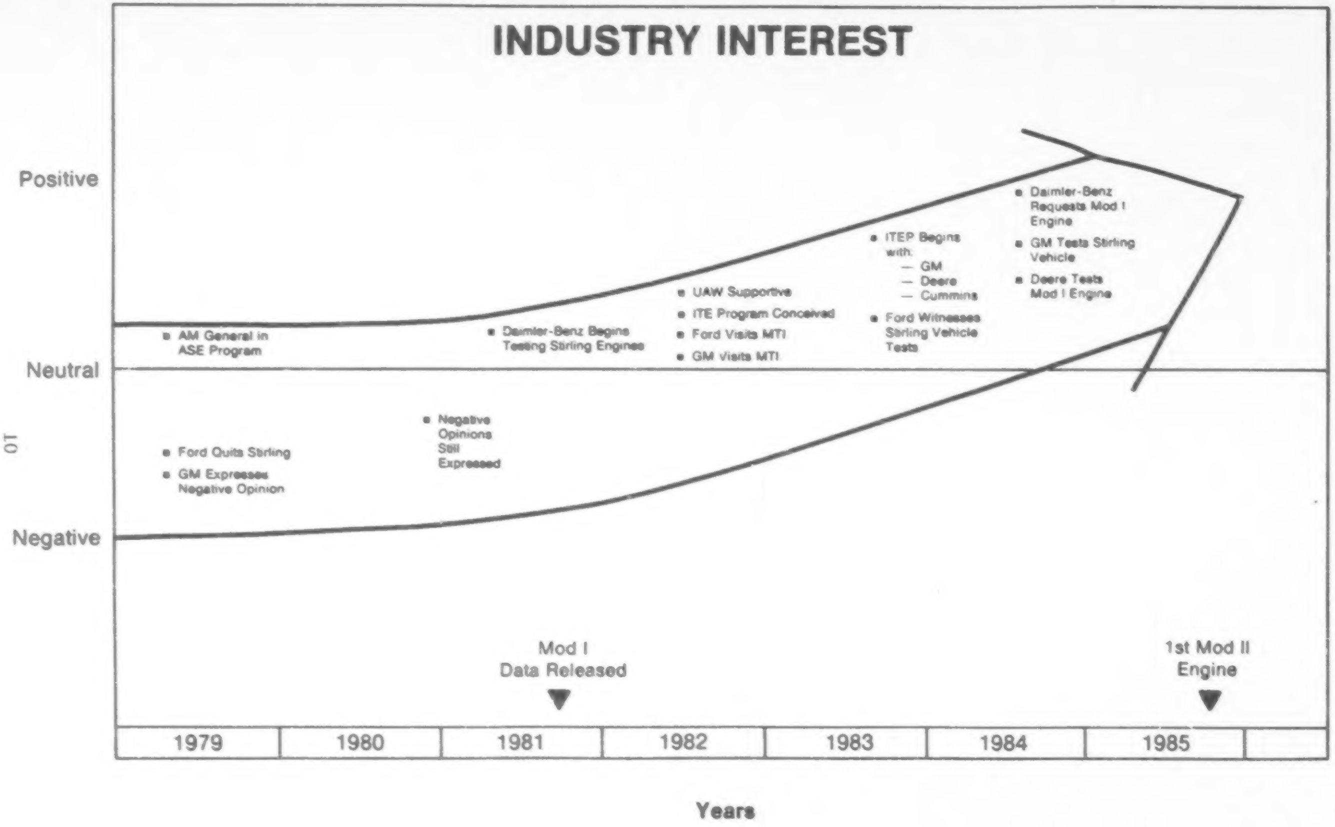

Fig. 5 Demonstrated Industry Interest in Stirling Engine Development

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STIRLING ENGINE PATENTS

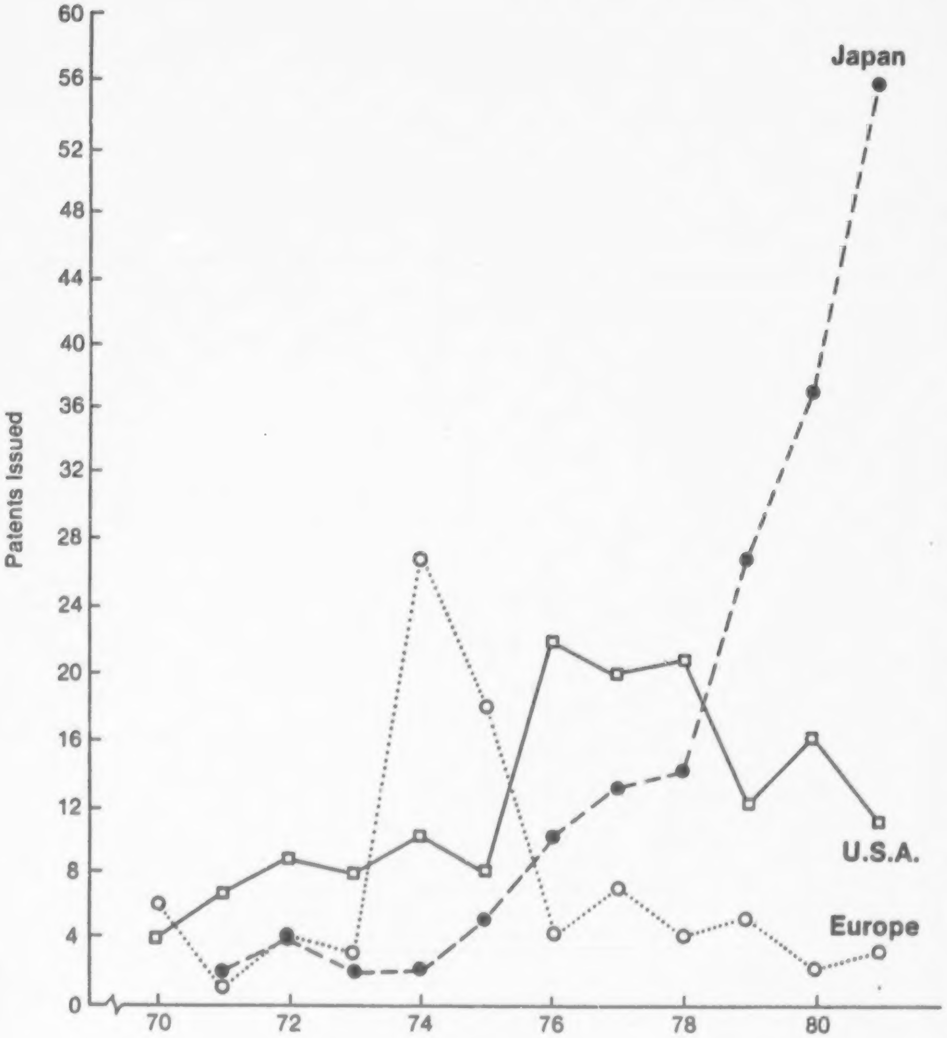

Figure 6

The Office of Industrial Conservation has, from the beginning, "done it right." In 1975-1976, I saw this office hire experienced people from industry who know the problems "in the trenches." In their new positions within government, these people continued to interact strongly with the industrial sector. Their doors have always been open to people from the private sector, and they have taken in and analyzed a multitude of ideas which came from the industrial sector, funding those which they considered the best, as funding was made available. They have also, nearly always, demanded cost share to ensure that the corporation was solidly behind its contractual activity. The results over the last eight years speak for themselves and are published in a document entitled "The DOE Industrial Energy Conservation Program; Project Description Sheets." This is a publicly available document from DOE, and I recommend that the committee maintain a file copy of it.

Mr. Chairman, I would suggest that the federal investments made by the Industrial Conservation Office are providing nationally beneficial results in goods-producing competitiveness, eventually resulting in lower energy use, reduced trade deficits, higher employment, and higher federal revenues. It could be argued that an investment by this office into the industrial, high economic multiple sector can pay for itself in a short time. This will happen if, in fact, the economic multiple for this investment, in a given year, is four, taxed at an average of 25%. Therefore, not only do we strengthen the nation with this kind of federal investment, but it can be argued that we even quickly get our money back!

In short, Mr. Chairman, if there is any part of the federal budget deserving of as much increase as it can creditably absorb, it is the DOE budget in energy-efficient technologies, particularly those programs funded by the Industrial Conservation Office.

Many of these industrial subprograms have been discussed in detail in past years before this Committee. There are two fairly new ones, however, which deserve special attention today. These are the Thin Strip Casting effort and the Advanced Steel Plant Study. To put these areas in perspective, I am going to make a few brief summary remarks concerning the steel industry.

The recent book by Bolling and Bowles, entitled "America's Competitive Edge," gives an excellent, short, readable overview of the nation's steel industry. The book depicts steel industry problems as a function of its history, and has an excellent chapter entitled "The Steel Industry: Opportunity for Revitalization." A key paragraph from this chapter reads:

> "In 1973, both Japan and the United States were hit with the price impact of the oil embargo. As energy prices shot up, so did the basic cost of steel in both the United States and Japan. Because Japan is resource poor and imports most of its energy sources, its industry had been conscious of energy costs during modernization. As might be expected, Japanese plant and equipment was far more energy-efficient than its United States counterpart. Basic costs - including oil, coal, natural gas, and electricity - were brought under control in 1975 and 1976 in the Japanese steel industry. They were not in the United States. Thus, a weakened position in energy completed the weakening of our economic triangle and contributed to the American steel industry's relative decline. The United States steel industry was not world competitive and was on the verge of

> partial liquidation by the end of 1976. Driven by higher energy costs and lower productivity in the United States, steel imports reached a new high of 19.3 million tons in 1977."

A final piece of background is presented from the journal of Japanese Trade and Industry: No. 6, 1982, pg. 28. In this journal is a description of the Ohgishima Steelworks, owned by Nippon Kokan K.K. That brief description follows:

Ohgishima Project - A Model Steelworks

During the 70 years since its foundation, Nippon Kokan K.K. (NKK) has undertaken many projects in keeping with the needs of the times. One of the most important examples was the construction of the Ohgishima complex with an annual crude steel capacity of 6,000,000 tons.

NKK's Keihin Works in Kawasaki suffered from various problems, including its proximity to urban areas, the small site, dispersed siting of manufacturing plants and superannuation of production facilities.

The Ohgishima project was designed to revitalize the Keihin Works. The project called for replacing the major facilities with a giant steelmaking complex on man-made Ohgishima island in Tokyo Bay. The land was reclaimed with 8.5 million cubic meters of earth - more than that dug to build the Suez Canal. The project, undertaken from 1971 to 1979, may be the last case in this century of an integrated steelworks being built completely from scratch in Japan.

In the past, most integrated steelworks construction in Japan was aimed at boosting production capacity. The Ohgishima project was an epoch-making undertaking in that it was aimed at increasing the efficiency of plant operation and preventing pollution.

The Ohgishima complex has the following three major features:

(1) Rational plant layout, up-to-date production facilities and high-level production control system.

In Ohgishima, the transportation system for raw materials and products is fully streamlined in a linear flow from east to west. Greater automation has been achieved through the adoption of up-to-date facilities for operations ranging from raw materials handling and transportation to pig iron production, steelmaking and rolling processes, and power generation. The plate mill can manufacture products of up to 5.3 meters in width and the hot-strip mill up to 2.3 meters, both the largest in the world.

The hot-strip mill is also a revolutionary plant, with the world's first automated slab and coil yards.

As for production control, on-line computer control covers operations ranging from the receipt of orders to final shipment, ensuring customers of high product quality and delivery exactly on schedule.

With these advantages the Keihin Works has emerged as an outstandingly efficient steel plant. Productivity (crude steel output per plant worker) nearly doubled from 240 tons in 1967 to 410 tons in 1981.

(2) Energy-saving measures

A. Representative of energy-saving facilities in the production process is its continuous casting lines which are important as well from the viewpoint of conserving resources. The continuous casting rate has been rising recently in Japanese steelworks. At the Keihin Works, the rate rose from 53% in 1978 to 90% in 1981.

B. Most energy generated within the complex, such as gas, heat and pressure, is recovered for effective utilization. All energy is centrally controlled by computer.

(3) Pollution prevention measures

About 20% of the total $36 million investment in the complex went to pollution prevention measures, such as minimizing the emission of SOx, NOx and dust. Efforts were made to improve the environment of the working site and neighboring areas.

NKK's Ohgishima project is a model of steel plant construction, an ideal example of a steel mill sited near an urban area and of the modernization of aging steelworks.

* * * * *

Mr. Chairman, the key point to be made is that the Ohgishima Steelworks was begun 15 years ago. In that 15 years, we in the United States have evolved a number of key technology improvements which, if implemented on a broad scale, could supersede the capabilities of Ohgishima. We need, however, to be smart enough to see the opportunity and seize the initiative. This then leads to two key projects:

Thin Strip Casting ($7 M).

- This process, if successful, can save substantial energy and cost in the production of steel products which make up nearly 50% of the steel market. The process would eliminate the reheat furnace and the hot mill used in present thin-strip production. The hot mill is generally the biggest investment within a steel mill and has the lowest reliability. Therefore, elimination of the hot mill eliminates the biggest item in both fixed costs and operating costs.

- For once, the Japanese do not yet have this process. This is a chance for us to "leap-frog" the competition.

- Feasibility studies were completed in January 1984, and the project is now ready for significant development funding.

Advanced Steel Plant Study ($1 M). Mr. Chairman, Ohgishima steelworks was begun 15 years ago. Now it's our turn. The $1 million to be spent on this study would address the feasibility and conceptual design of a major steel-producing facility which would produce 6 to 8 million tons annually. It would incorporate the lastest technologies such as Direct Smelting, Hierarchy Computer Control, Advanced Sensors, and Thin Strip Casting. It would be placed in a location such as offshore on a man-made island in Lake Erie, allowing ore boats to unload on one end of the island and finished products to leave from the other end via boat or causeway. Financing and ownership options should be examined including optional roles of government. The latest pollution control technology would be employed. In short, this study would integrate the best available and developing steel technology into an entity which would, once again, put our nation into the forefront of steel production, an area with a very high economic multiple.

This ends my discussion of DOE's industrial program.

GAS HEAT PUMPS ($7 M - FY85).

I have one other subject to address today, Mr. Chairman, if I may be allowed. That subject is heat pumps which operate from natural gas or fuel oil. These are generally referred to as Heat-Activated Heat Pumps or Gas-Fired Heat Pumps. For FY85, this area requires $7 million.

In the United States, there are 40 million single-family residences which utilize gas as a source of heating fuel. Thermal heat pumps burn conventional fuels such as natural gas to produce space heating and cooling at exceedingly high efficiency. Compared to the best possible combustion furnace systems, thermal heat pumps offer the potential to realize significant energy savings of up to 4.5 Quads of Energy in the United States residential sector and to provide enhanced security during sudden fuel dislocations.

The Japanese and German governments have initiated significant programs in excess of $10 million per year directed toward developing both the long and near term technology options to capture the potentially large worldwide market. Comparable development efforts need to be pursued in the United States to forestall foreign competition and to ensure that American industry will be able to compete in domestic and foreign markets for heating equipment customers during the late 1980s and 1990s.

The Gas Research Institute, reacting to industry pressure, has elected to place an increasing emphasis on low risk technical options. However, greater national benefit could be achieved from the more advantageous operating characteristics associated with advanced, longer term options.

Several attractive long-term technologies have been identified as having significant potential to succeed in the residential sector. Specifically, free-piston Stirling engines, free-piston internal combustion engines, and double effect absorption cycles show a good probability of providing the reliable, long-life, high-efficiency operation required of heat pump systems. Based on their relatively early stage of development, it is not evident which technology has the highest probability for long-term success. Therefore, multiple program paths need to be pursued to ensure a reasonable chance for achieving success.

Due to the high technical risk associated with long-term heat pump options, private industry cannot bear the long-term development costs. The burden of development needs to be supported by public funding.

Previous levels of public support are not sufficient to insure that American industry will be technologically able to thwart future foreign competition. In FY85, the United States Heat-Activated Heat Pump Program requires $7 million in appropriations of which $6 million would go to prime contractors, and $1 million would be used by DOE and Oak Ridge National Laboratory for management and supporting research. With these funds:

- The critical technologies required for reliable long-life in heat pump prime movers will be developed.
- Laboratory prototypes will be designed leading to fabrication of units that will verify the efficiency potentials of the various options.
- Critical components will be developed for reduced fabrication costs.
- Supporting research will be conducted on materials, fluids, dynamics, and mass and heat transfer.

This program is vital to America's long-term interests in the residential equipment market, and needs to be strengthened and accelerated in order to ensure that we maintain a competitive edge in the domestic residential market and preserve future opportunities in the international market. Success will provide an improved standard of living for many Americans, an improved balance of trade, conservation of resource, and enhanced employment opportunities.

Conclusions

Watching the FY85 budget process, Mr. Chairman, the casual observer notices a tug-of-war between expenditures for enhanced defense and funds for social welfare: two sectors with decidedly low economic multiples. Being almost completely neglected is that sector which has played a major role in pulling the country out of prior economic difficulties: the high economic multiple, goods-producing sector. While we build our defense capabilities, foreign interests control more and more of our cash and our industrial base. While we defend against foreign military takeover, we are experiencing a gradual, foreign economic takeover. Clearly beneficial areas for federal expenditure are those areas of high economic multiples, on projects which are energy conserving, cost reducing, of substantial projected benefit, and including either risks, costs, or payback times which make private sector investment unattractive. The Conservation Technology Programs in DOE are clearly such investments and should receive maximum federal attention.

Senator Evans. Thank you very much, Dr. Lawrence. Let me go back if I can and ask at least a few questions of each of the witnesses.

I was particular interested in the similarity of Dr. Ridgway and Mr. Anderson's testimony. How similar are the two operations? Dr. Ridgway, would you like to comment? Are you competitors? Cohorts?

Dr. Ridgway. We are competitors.

Senator Evans. It is sea technology essentially, is that correct?

Mr. Anderson. It is only the same in the sense we are both using the ocean thermal energy. From there it departs quite widely.

Senator Evans. OK.

Dr. Ridgway. And R&D Associates' main business is studies for the Defense Department. We do have a small part which is interested in energy research matters and we have been pursuing this concept under DOE funding since 1977, and when we were most—as our work was being crowned with success, the amount of money that we got to continue shrank drastically and so we just haven't gone really very far since 1980, 1981.

Senator Evans. How far? You know, how far have you gone? Where do you really think you are at this point?

Dr. Ridgway. What we have done is that we have proved the basic concept and we have answered some of the technical questions in order to convince any banker that he ought to invest some money and that he has to see this thing operate on a larger scale. Larger scale experiments need to be done, and the present experiments were done in a column that was 12 feet tall and about a foot square, and the next step would be to approximately double the height of the column and double the flow rate, and then the step beyond that is something perhaps 60 to 80 feet tall, and stepping a little bit further because each time in chemical engineering that you go from a laboratory scale experiment to pilot scale experiment, to a larger, full-scale experiment, new problems come up which you have to learn what it will cost to take care of them.

Senator Evans. You said in your paper that a recent cost estimate indicates that this should cost between $1,500 and $2,000 per kilowatt. That is a familiar statement. Probably the same things were said 15 years ago about nuclear plants. They should cost between $1,500 and $2,000, which is probably right, but they seldom do.

Dr. Ridgway. What we haven't done, you know, is we haven't gone around with a set of plans to construction people and saying all right, we are ready, make us a bid, that we can count up how much concrete and how much iron and how much vacuum pump. The rest of it, rotating hydroelectric machinery, is fairly conventional and we can cost that fairly well, so it doesn't have the potential—we don't have a waste disposal problem. We don't have a safety problem for the general public. There is very little to it, and so there is very little that is going to get more expensive as the development goes on.

Senator Evans. I would guess, just looking at the small diagram you have here, that probably it is accurate that something of that, reasonably that size and simplicity could be built. Somebody could estimate and get the cost down and build it to that cost.

The other half of it, however, is the efficiency of the operation and the amount of electricity you get out of the process.

How sure are you of that side of things?

Dr. RIDGWAY. Well, we are extrapolating from the 12-foot-high experiment, and it is a fairly long extrapolation, so we want to do a 24-foot high experiment, and from that we will be pretty sure about the efficiency.

Senator EVANS. How much do you estimate a 24-foot-high experiment would cost?

Dr. RIDGWAY. Oh, $300,000.

Senator EVANS. You have talked about the cost per installed kilowatt. How would that translate into cost per average kilowatt of energy produced, kilowatt hour?

Dr. RIDGWAY. At $2,500 per kilowatt of capacity, and if you had burned imported oil instead, it is an even tradeoff, so that the cost of the oil is the interest on the plant, so you could afford to not build an oil plant and put this in its place. Forget what you had invested in the oil plant and get electricity for the same amount of money.

Senator EVANS. I only have one question on something that you had in your paper. You are talking about the manufacturer already profiting by selling oil, coal or nuclear power generator technology. Maybe so on northern coal; I doubt very much that anybody has made much money recently on selling nuclear power technology.

Dr. RIDGWAY. All right.

Senator EVANS. OK. Mr. Anderson, your turn—would you like to describe in a little more detail, well, the difference in the processes?

Mr. ANDERSON. Well, the fundamental difference in the process between what Dr. Ridgway is discussing and our process is that we are merely taking warm water and using it to boil a refrigerant—ordinary household R-22, the same thing that is in a household refrigerator.

That then is passed through——

Senator EVANS. A big heat pump? Is that what you are talking about?

Mr. ANDERSON. Well, the reverse.

Senator EVANS. The reverse, right.

Mr. ANDERSON. And so the R-22, the ordinary refrigerant, then turns a turbine. It must then be condensed in condensors which are cooled by the cold water, and then it returns and repeats the cycle.

We have been working on this now for over 20 years, and therefore we have had the time to make many improvements and also to evaluate the process and the design of the plant and how it can be improved to the point where we now know that we can get a cost of a thousand dollars. As a matter of fact, in talking to shipbuilders, the cost should be about half that, per kilowatt generally.

We also know that with this design we can get up to 90 percent easily of availability factor, whereas the average availability in nuclear plants historically has been only 55 percent. All of these factors contribute to saying that the cost, the effective cost as stated here of a plant is down to $1,111 a kilowatt and eventually will be less which will make it less than one quarter the cost of nuclear power or coal power and less than half, by far less than half the cost of presently produced oil power.

Besides this, of course, this has the advantage that it is environmentally—everybody, NOAA and many people have studied the environmental impact of such a system, and it is I think pretty universally agreed this is the most environmentally benign source of power on the face of the Earth. As a matter of fact, peculiarly enough, this will reduce acid rain. It will not only reduce it because it doesn't produce any, but the very process of taking the warm water from the surface of the ocean and putting it through the plant means that you make a new surface available which can absorb more acid from the atmosphere, so that this actually in a small way reduces the acid in the atmosphere, so that all in all, it is the most benign power process. It is going to be the cheapest one. It has many advantages in that it will produce large quantities of food. It can produce hydrogen. It can produce methanol. It can produce ammonia. It can produce all kinds of chemicals so that there is no question about it, that this is the coming most important source of power on the face of the Earth.

Senator EVANS. You say you have been working on this 20 years. Has it all been design work? Is there any pilot plant of this type being constructed?

Mr. ANDERSON. We actually built the first pilot plant that was built back in 1972 when there was, started to be a little interest in that. Many distinguished people said well, you can't even run a turbine with such a small temperature difference in the ocean, so we actually built a small powerplant and demonstrated that we could run a turbine and run a plant that way. Now that was the first powerplant that was ever built, and since then, of course, the Japanese have built some. We have built others in this country, so that everybody now agrees that the system works, but that was the first pilot plant ever built that actually generated electricity.

Senator EVANS. How big a plant was it?

Mr. ANDERSON. That was 100 watts, enough to light a few light bulbs.

Senator EVANS. How about Japan? What is the largest plant to your knowledge that has been built any place in the world?

Mr. ANDERSON. As far as I know, the Japanese have built an island-based plant of 100 kilowatts. Now I have heard reports that they have presently built some larger ones, but I am not up to date on that so I can't say for sure, so the point is that there are many demonstrations to prove that the system works.

The real crux of the situation is it requires the innovation in design which we have provided to recognize that the cost of this system is really the way to the plant, and we have, with steady development on all the phases of the plant, we have successfully brought it down so we know that a plant will weigh less than 25,000 pounds, and simple shipbuilding practice will tell you how much that costs.

Senator EVANS. This would be essentially a reinforced concrete——

Mr. ANDERSON. Oh, no. This would be a very ordinary construction similar to that used in oil drill rigs which would—fundamentally shipbuilding construction of steel, aluminum and ordinary material.

Senator EVANS. Dr. Ridgway, could you explain a little more than the different technique or the different principle involved in what you are talking about from the one that I understand reasonably well that Mr. Anderson mentioned?

Dr. RIDGWAY. Dr. Anderson transfers heat to working fluids. He bils the working fluids, runs the working fluids through a turbine and condenses it.

In the mist lift process, the working fluid is water vapor. The water, warm water from the surface of the ocean, is sprayed into the bottom of the column or the plant that you see on the figure, and the pressure down there is maintained about half a pound per square inch absolute. It is a pressure slightly below the saturation vapor pressure of the warm water.

This warm water, then it sees an environment where the pressure is less than its vapor pressure, and it quickly evaporates in a few hundredths of a second about 1 percent of its mass into water vapor, and this would be a pressure of about half a pound per square inch absolute.

Higher up in the column, the cold water is introduced at a lower temperature such as say when the warm temperature water is introduced at 25 degrees Centigrade, it flashes down to about 17 degrees Centigrade. The cold water makes the lower pressure in the top of the column so the steam, the water vapor, flows from the high pressure area at the bottom to the lower pressure area where the cold water is introduced, so the steam moves at a velocity of 30, 40, 50, meters a second, depending upon the design choices we make, and it drags the water droplets upward to a velocity of about 40 meters a second.

Then the cold water and the mist, they all merge and collapse and go up to the top and go out. The central thing is that it is a pump. What it does is that it pumps water up a height of 100 feet or several hundred feet, and then you get the energy out by allowing the water to fall through an ordinary hydroelectric plant, so you can look at the walls of the plant. It is kind of being like a dam. Then you allow the ocean to fall through the height into the bottom of the powerplant and the bottom of the dam, and then you pump the water out of the bottom, up the thing and out.

The ocean temperature difference is the source of the energy that makes the pump run, and where does the economy come from? Well, the economy comes in that first, the heat exchangers are just the surface of the water droplets and so one could provide enormous heat transfer areas at very low cost.

And the second economy is that if I elect to transfer the heat energy to water vapor, if I choose water vapor as my working fluid, I now have to extract my mechanical energy out of that water vapor. The original Claude cycle used a turbine to take the energy out of the water vapor, but the size of this turbine was enormous because the density of that vapor is so low, and the force depends upon the density times the square of the velocity.

Now this thing, it is not the density of the vapor which enables you to do the work on the water droplets but the viscosity, and viscosity of the lower pressure gas is the same as the viscosity of an ordinary pressure gas so the water droplets are dragged up by the viscosity of the moving water vapor and lifted up to absorb the work from the water vapor.

Senator EVANS. That is a fascinating concept. I have got your testimony earlier on the tradeoffs and the costs of another experiment.

Did I understand you correctly to say that with a 24 foot or an 8 meter experiment, that that would be sufficient to prove the technology, that you could jump from there to a commercial size? Are there other elements in between?

Dr. RIDGWAY. Well, I mean you should always do the intermediate step for the engineering purposes, but at the present, a powerplant, I have a very small data base. I have one density of mist generator spray paint. I have to exert the whole thermal dynamic work of the cycle in a height of 12 feet in order to test it, and that is not an advantageous place to do it. I would rather do it in 24 or 30 feet.

Now if I do, if I test it out at 24 feet and find that the predicted increase in efficiency actually takes place, you know, then I am quite confident that the plant will come in at $2,000 a kilowatt, and if it turns out that if I do an experiment 40 or 50 feet high and find that the further predicted increase in efficiency takes place, then the cost will come down some more.

Now the $1,500 to $2,000 a kilowatt that I put in the testimony has got a little bit of extrapolation from the data base which I am quite confident, you know, that experiment will show that it wasn't hopeful or unrealistic, but the experience of the lab has been that generally nature has been kind to us, and things have worked better than we thought they were going to rather than finding that we had to spend 6 months chasing down little difficulties or being given elaborate complications or taking care of problems that we hadn't anticipated beforehand.

Senator EVANS. Is your estimate—the one that is shown here in the diagram shows about a 100-meter lift. Is that correct?

Dr. RIDGWAY. Yes.

Senator EVANS. Do you anticipate that that is a, well, is that the maximum or is that just kind of an intermediate stage?

Dr. RIDGWAY. A hundred meters is probably the maximum that you want to try for. The theoretical maximum, choosing three parts of cold water to one part of warm water, is 164 meters, and you would rather not, maybe might not want to use so much cold water because that is going to cost more than the warm water, so somewhere in the 80 to 120 meters looks like the optimum design based on what we know now.

Senator EVANS. When you talk about warm water, cold water, what are you talking about in temperature?

Dr. RIDGWAY. Twenty degrees Centigrade difference.

Senator EVANS. OK. Gentlemen, the ocean, how far down do you have to go to get to 20 degrees Centigrade difference?

Dr. RIDGWAY. About a thousand meters off of Hawaii. Elsewhere, I don't remember.

Senator EVANS. OK. Let's turn to Mr. Lang. On page 3 of your testimony you say, "Analysts generally agree that a U.S. energy consumption in the year 2000 of around 100 quads should provide for a healthy economy."

Do I understand correctly that current is what, 70?

Mr. LANG. Seventy to eighty.

Senator EVANS. There are some who suggest—you may have heard an earlier question along this line. There are some who would suggest that energy conservation or increased efficiency could handle all of the energy needs between now and the year 2000, and that there is no real reason we need any more energy than approximately the current amount if we had the efficiencies which are available out there.

Do you agree or disagree with that?

Mr. LANG. Well, I would disagree slightly in that I guess you can get any range of answers as to what the energy needs would be in the year 2000. There have been some that are as low as what we are today using which is around 80 quads.

I think the thing that is, that is our position, is that there are, obviously there are many opportunities for conservation and they all ought to be pursued, but on the other hand, there is going to come a time when new technologies will be required for energy production, and I don't think we should be lulled by the fact that there may be a gap in which this conservation can tide us over for the foreseeable future, but ultimately we have to come in with new technologies and new sources of energy supply.

Senator EVANS. There are some who suggest that all of this fussing around with energy research from the Government level is not really necessary and that the market itself will push us fast enough into new energy sources.

What do you think about that?

Mr. LANG. Well, I think that the market has done a lot of pushing in the, perhaps in the past 10 years. I don't think that the market will necessarily provide the basic research requirements that are needed to bring some of these technologies to the point where they will become commercially reasonable. I think you need a mix of both.

Senator EVANS. There are some who would suggest that if Government had artificially tried to keep the price of oil down a century ago, there would have been delayed discovery of oil in Pennsylvania.

Mr. LANG. Possibly.

Senator EVANS. Do you have any view as to what we can look forward to? You mentioned in your testimony that we have had increases of efficiency at about 0.5 percent a year from the forties to the midsixties, and that certainly wasn't price drive. Energy prices were pretty stable during that period of time, and then the rate of improvement is achieved about 2 percent a year in the late 1970's.

Do you have any feel at all as to what we should be able to expect in efficiency or in that measure of efficiency at least in the years to come?

Mr. LANG. I guess our feeling is that those particular rates of increase can be sustained and can be improved. There are a number of industries that have made great strides in improvement in energy consumption, and they feel that there is still a lot to be gained, so I think there is still a lot there.

There is no reason that we can't do that. I think the problem arises in that it becomes more difficult as time goes on obviously. The easy fixes are gone. There are many areas, though, that can take attention and will provide some increases in conservation.

Senator EVANS. One of the difficulties you ran into in building the Northwest Power Plant was in trying to ensure that the right signals were sent out. In many cases what is cost effective in terms of region isn't cost effective in terms of an individual consumer or even an individual corporation.

We asked many of the industrial plants in the Northwest what they could come up with in the way of energy conservation, and they said it was terribly difficult. They had all sorts of reasons why they couldn't come up with very much, and we asked them what the pay-off period was before they got interested in that, and they are down to 18 months or something like that.

Well, it is clear that something may well in longer term be cost effective, but with their limited capital, they said we have just got other things that appear to be more important to us, and unless we get a payoff that rapidly, we are not likely to make the investment.

Has your organization done any kind of work at all in looking at what might be achieved by just simply buying in this case electrical energy, wherever we buy it. We are building nuclear coal plants. Can't we buy it by buying insulation, or buying more efficient processes in our industrial plants? We seem to have great difficulty in suggesting we are giving something to an industrial plant, but if in fact we look at it as buying electricity cheaper than we can get it any place else, what is wrong with it?

Mr. LANG. Our particular group has not looked at that specifically. That is being done in a lot of areas. There are a lot of programs that are available to utilities that do pay for certain conservation measures.

Senator EVANS. They tend to be focused primarily on residential, to a lesser degree on commercial. There are hardly any that I am aware of to any great extent in the industrial field where there is potentially a whole lot to be made.

Mr. LANG. We have been driven pretty much by price so far.

Senator EVANS. OK. Dr. Lawrence, could you talk a little bit more about the Stirling? Well, describe for the record the essence of the basic process of the Stirling engine.

Dr. LAWRENCE. Yes, sir, certainly; there are a wide variety of designs and shapes and sizes of Stirling engines, but they all operate on one basic, simple principle, and I think it is the same one that most of us saw in science class in high school. You blow up a balloon and put it in a hot place and the balloon gets bigger and you put it in a cold place and the balloon gets smaller, and basically what that says is that if you heat and cool a sealed-up gas, it will expand and contract.

Basically what you are doing with a Stirling engine is you seal up a gas in a compartment, and you naturally heat it and cool it in some fashion, and when you heat it, it pushes on the piston at one end of that compartment. When you cool it, it pulls on that piston, so at all times you are actually operating on this piston with this cycle, and it becomes a highly efficient process in that way.

If you take that basic concept and then are able to get to a point in the technology where you can alternately heat and cool a gas 4,000 times a minute, then you get a 4,000-r/min engine which we have presently operating in automobiles through this program.

The engine itself is a very versatile and flexible engine because instead of having to put fuel and air down inside it, now what you actually have is an enclosed flame on the top of the engine which provides the heat which is then alternately transferred to these various cylinders, and since it is a flame, you can operate the engine on any liquid fuel interchangeably that you want to put in the tank, and we have done that pretty routinely now.

Also since it is a flame, the flame is the most efficient form of combustion, and therefore the environmental aspects are very good because the products of combustion are what they say fully combusted so that you don't get the pollutants to the degree you would with an explosive, fully mixed process.

We have come from 1978 at which time no one had successfully introduced a Stirling engine into an automobile to a point today which it is purely coincidental, Mr. Chairman, but it turns out that today is the day that we delivered an automobile with a Stirling engine in it to General Motors for their test and evaluation—the first time that they have actually participated in this program with their own funds, and they are taking this Mod 1 engine and automobile, putting it through an exhaustive series of tests up in Michigan.

We have shown to date that the Mod 1 engine, the first one in the program of automotive design, an engine based almost entirely on Swedish technology, has been a success. We have alternately run various liquid fuels in it. We have met the 1985 emission standards in the laboratory. We have been a little bit over on the highway, and the engine has shown the kind of promise that the program originally thought it would, that the JPL study said.

Well, the Mod 2 engine is the one that is really the proof of the pudding if I can use that idiom because it incorporates all of the technology that has been developed under this program in the United States into an engine design which is going to meet every goal of the legislation and the contract—pretty remarkable—and do it on time, and within cost, and on schedule, and all these kind of things which are, as you know, fairly rare in Government programs.

The status of it today is that thanks to the tenacity of the Congress, we are beginning to get preliminary but significant industrial interest. We have not had that prior to the last couple of years. In fact, 4 years ago as you can see in my chart on page 10, there were industrial people out there who were actively trying to kill the program. In fact, they were working with the Congress in an attempt to kill the program and today we find the same industrial people actually starting to spend a little bit of their own money to work with us, so we have come a long way.

We have a significant way to go. It is not ready for commercialization. The Mod 2 is the final engine of the contract. It always has been the final engine of the contract, and we are not requesting Government money beyond what the contract has stated, and I guess that is in a nutshell where it is.

Senator **Evans**. What would your estimate of the performance functions in the Mod 2 engine be?

Dr. **Lawrence**. Based on a one-for-one switch where you don't change anything in the automobile except the engine, based on the size and shape of the car itself, the Mod 2 should get improved gas mileage of between 30 and 50 percent better gas mileage than the cars originally had, and that again depends on which car you put it in.

In terms of the goal of alternate fuel use, it will use any liquid fuel that you want to pour in the gas tank interchangeably. It will meet the 1985 emission standards. Its size and weight will be comparable to automotive engines today.

It will not contain any exotic materials, and its price on a production basis should be slightly less than an automotive diesel today.

In terms of its acceleration, it should be in between a diesel and a spark ignition engine.

Senator **Evans**. Do I understand correctly then the nature of the automobile engine that you are talking about, actually is the power transmitted through positive displacement or through turbine like?

Dr. **Lawrence**. It is through positive displacement. It actually is a four cylinder block. The Mod 2 is a B and the Mod 1 that we are working with the Swedish design has four cylinders and what they call a U configuration. It does require seals which has been an extensive part of the expenditure on this program.

We have been very successful in our seal development, but the seal actually seals up each piston and cylinder. It seals it at the piston rod, and the gas above the piston. The piston has rings like any other piston, is alternately heated and cooled so that is the manner in which the piston initially goes up and down.

Senator **Evans**. You say heated and cooled. What kind of heating and cooling occurs in that appropriate time? You talk about a 4,000, rate of 4,000 per minute?

Dr. **Lawrence**. Yes. It has some passages and heat exchangers that the gas is actually pushed through, and the way it is designed, it moves from one cylinder to the next and back, and as it moves in one direction, it is cooled, and in the other direction it is heated. That is because you have got a hot heat exchanger on this side and a cold heat exchanger on this side, and the heat is provided by a flame that encompasses the outside of the hot heat exchanger. It is cooled by water which circulates around the outside of the low temperature heat exchanger, and in between there is a thing called regenerator which actually retains heat and helps in the performance in between the cold and hot heat exchangers.

Senator **Evans**. I am still curious about what, or what kind of temperature changes you get.

Dr. **Lawrence**. OK. The high temperature is about 800 degrees Centigrade or 1,500 Fahrenheit, and we have found some materials identified by NASA actually that work very well at those temperatures, so we are beyond any kind of high temperature material problems. The materials are inexpensive.

The low temperature we keep at 50 degrees Centigrade which I guess is about 120 degrees Fahrenheit, and it is cooled with a radiator on the front of the car that is a little bigger than your standard radiator—not an awful lot bigger—but that provides the coolant.

Senator EVANS. Very interesting; I think I am out of questions. Does anyone have a final comment before we adjourn?

[No response.]

Senator EVANS. If not, thank you very much. It has been a most interesting panel and this record will be very helpful to us as we get through our budget elements for this year and work on the continuing programs in Energy R&D. Thank you very much.

The hearing is adjourned.

[Whereupon, at 11:50 a.m., the hearing was adjourned.]

APPENDIX VIII

RESPONSES TO ADDITIONAL QUESTIONS

Department of Energy
Washington, D.C. 20585

June 22, 1984

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
  Research and Development
Committee on Energy
  and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On April 24, 1984, Under Secretary Pat Collins appeared before the Energy and Natural Resources Subcommittee on Energy Research and Development to discuss the FY 1985 authorization for Conservation and Renewable Resource Programs.

Following that hearing, you submitted written questions for our response. Enclosed are the answers to those questions. Copies Have been provided directly to Mr. Gilman and Mr. Astrin.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

for Thomas H. Pretorius
Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Paul Gilman
Mr. Al Astrin

QUESTIONS FROM SENATOR CARL LEVIN
Energy Conservation Technology R&D Plan

Question 1: The Department of Energy recently released a report entitled, "Energy Conservation Technology R&D Program Plan", dated January, 1984. The preface indicates that this document is the first revision of a draft Energy Conservation Technology R&D Program prepared by the Conservation Program Offices in October 1983. According to the document, it is intended "to provide the management framework for a well-defined, directed conservation program." I don't think you mentioned this document in your testimony--I wonder, is this an official Administration document or what? What is your view of this document and its purpose and status?

Answer: The FY 1985 Energy Conservation Technology R&D Program Plan is an internal working document used by the staff as a planning tool. It is not an official Administration document, nor is it a budget proposal. Nevertheless, we feel that it is useful as input to the budget process. It presents a technical assessment of energy conservation technology R&D priorities to the year 2000. It articulates a technical basis for many of the proposals ultimately presented on the President's FY 1985 budget request.

These proposals should be considered within the context of a set of priorities used as input for discussion and budget formulation and should not be considered as budget proposals unto themselves.

QUESTIONS FROM SENATOR CARL LEVIN
Energy Conservation Technology R&D Plan

Question 2: This document states on page v that the energy conservation annual budget has ranged from $174 million to $386 million and that the minimum acceptable budget for the first planning year (FY 1985) should not be less than $145 million. A high option is discussed as a planning level and it calls for a budget for energy conservation technology of $197 million. Where does the administration's FY 1985 budget request fit into this? More particularly, should the multi-sector programs be considered a part of what is specified in the Energy Conservation Technology R&D Program Plan?

Answer: The FY 1985 Plan proposes a range of budgetary considerations and, by inference, a set of project priorities. These proposals predated the Administration's official budget request. Although the Plan and the Budget Request are similar, there are differences, the latter having resulted from final Administration review and approval. In accord with the budget structure, the multi-sector programs are considered part of the overall Plan. The Administration's FY 1985 request for Buildings, Industry, Transportation, Multi-Sector (ECUT), Energy Storage and Electric Energy Systems programs is $176.5 million. This amount includes funds required to support congressionally mandated energy conservation programs. This amount is above the Plan's low option, but below the Plan's high option.

QUESTIONS FROM SENATOR CARL LEVIN
Energy Conservation Technology R&D Plan

Question 3: If the Congress were to adopt the high option approach what would we appropriate in FY 1985 for energy conservation technology?

Answer: Energy Conservation Technology is defined to include funds for R&D programs for Buildings, Industry, Transportation, Multi-Sector (ECUT), Energy Storage, and Electric Energy Systems, all technology transfer efforts, and funds for program direction. This definition excludes funds for carrying out congressionally mandated programs. Given this definition, the totals in the Plan for "energy conservation technology" total $137.5 and $187.4 million for the low and high options, respectively. Again, these options should be considered within the context of a set of priorities used as input for discussion and budget formulation and should not be considered as budget options unto themselves.

QUESTIONS FROM SENATOR CARL LEVIN

Energy Conservation Technology R&D Plan

Question 3a: This document further states, "At both budget levels a provision is made in the program for a planning wedge of new project starts." Does your FY 1985 budget request include all the new project starts associated with the high option planning level for FY 1985? If not, can you tell us which new planning starts for 1985 are missing?

Answer: The concept of a "planning wedge" is for the outyears, beginning with FY 1986. As R&D projects come to a close, others must compete to fill the "wedge" in the outyear budget projections. A planning wedge is assumed even in a declining budget scenario. As for the differences between the high option in the Plan and the Administration's budget request, all new starts identified in the Plan are for fiscal years 1986 and beyond and hence cannot be compared to the Administration's request for FY 1985.

QUESTIONS FROM SENATOR LEVIN
Methanol

Question 4: Your Energy Conservation Technology R&D Program Plan places considerable emphasis on the importance of methanol as a substitute fuel for automobiles, yet in your FY 1985 budget request you apparently have no further funding requests for alcohols in the alternative fuels utilization program. The budget book simply states that the alcohol project was completed in FY 1984. Has all the necessary work on methanol as a suitable fuel for motor vehicles been completed now? If so, what is your conclusion?

Answer: With anticipated completion of projects investigating the fundamentals of wear in cold engine operations and cold-start/cold-driveaway problems, when using methanol, the development of a data and information base for use by industry and academia will essentially be completed. Use of oxygenated hydrocarbons (including ethanol and methanol) as a blending component for gasoline has been commercialized and, once market introduction problems are shaken out, will become established in practice. In 1983 about one percent by volume of the automotive fuel was oxygenated hydrocarbons, contained in perhaps 10 to 15 percent of the finished fuels. About 900-1,000 neat alcohol-fueled experimental vehicles are in commercial operation, and over one half of these represent second-generation, factory-designed units. Performance of these vehicles is generally very good. Although there is still room for increased efficiency, and the automotive industry will desire improvements before reaching commercial production, technology is not the limiting factor.

QUESTIONS FROM SENATOR LEVIN

Photovoltaics

Question 5: You no doubt are aware of the controversy surrounding efforts of other nations particularly Japan to surpass the United States in photovoltaic technology. Why does your budget request for FY 1985 represent a 6% decrease (before inflation adjustments) from the level of appropriations for FY 1984 for photovoltaics?

Answer: Actual year to year needs are based on progress as well as being heavily influenced by industry cost sharing on government contracts and privately funded research and development. For FY 1985, it is estimated that all sources of funding when combined will result in total photovoltaic research expenditures in excess of $100M. At this level of effort, the 1985 milestones are expected to be met. This funding level is significantly higher than those levels being planned for Japan and the European Community combined.

QUESTIONS FROM SENATOR LEVIN

Solar Energy R&D Evaluation

QUESTION 6: Has the Department developed a solar technology program plan including budget figures for planning purposes as you did with energy conservation? Are you planning to do so?

ANSWER: The Department is in the process of completing a strategic evaluation of renewable energy technologies which employs a uniform set of evaluations or criteria relating to the potential payoff of technology options; critical technical development objectives; priority of potential R&D activities; and the appropriate federal role in performing activities of high research priority. A draft document summarizing this evaluation is currently under preparation and is expected to be available for external review and comment in the July/August timeframe.

Question 7 : Please provide for the record a program-by-program (energy conservation and renewables) list of the spend-out rates by quarter for FY 1983. Please indicate the respective FY 1983 appropriation for each program and the unexpended amounts remaining at the end of each quarter.

Please prepare the same list for the first and second quarters of FY 1984.

Answer: This information is provided on the following exhibits.

FY 1983 Renewable Energy Obligations

(Dollars in millions)

	FY 1983 Appropriation	Unobligated Carryover	Total Obligation Authority	First Quarter		Second Quarter		Third Quarter		Fourth Quarter	
				Oligations	Unobligated Balance	Added Obligations	Unobligated Balance	Added Obligations	Unobligated Balance	Added Obligations	Unobligated Balance
Solar Energy											
Buildings	$ 11.6	$ 1.0	$ 12.6	$ .5	$ 12.1	$ 2.1	$ 10.0	$ 5.0	$ 5.0	$ 4.5	$ .5
Photovoltaics	57.9	0	57.9	8.7	49.2	9.8	39.4	26.5	12.9	11.9	1.0
Solar Thermal	49.4	4.1	53.5	6.4	47.1	16.2	30.9	7.4	23.5	14.1	9.4
Biofuel	20.9	1.0	21.9	2.0	19.9	6.2	13.7	8.9	4.8	4.5	.3
Wind	31.4	0	31.4	6.4	25.0	3.7	21.3	20.2	1.1	1.1	0
Ocean	10.5	4.4	14.9	.6	14.3	1.4	12.9	4.0	8.9	7.3	1.6
International	10.0	0	10.0	-.1	10.1	9.6	.5	-.2	.7	.2	.5
Tech. Transfer	3.0	0	3.0	0	3.0	.6	2.4	.8	1.6	1.4	.2
Program Support	1.0	.1	1.1	.3	.8	.0	.8	0	.8	.7	.1
Reserve Account	0	4.4	4.4	0	4.4	.1	4.3	0	4.3	4.1	.2
Prog. Direction	5.9	.3	6.2	1.1	5.1	1.1	4.0	1.7	2.3	1.3	1.0
Total Solar	201.6	15.3	216.9	25.9	191.0	50.8	140.2	74.3	65.9	51.1	14.8
Geothermal											
Geopressured	8.4	0	8.4	1.1	7.3	2.3	5.0	1.2	3.8	3.8	0
Geo. Tech. Dev.	15.0	0	15.0	3.1	11.9	9.5	2.4	.9	1.5	1.4	.1
Hydrothermal	33.0	23.6	56.6	-.1	56.7	2.1	54.6	-.2	54.8	52.3	2.5
Prog. Direction	1.3	0	1.3	.3	1.0	.4	.6	.1	.5	.2	.3
Total Geothermal	57.7	23.6	81.3	4.4	76.9	14.3	62.6	2.0	60.6	57.7	2.9
Hydropower	2.0	.3	2.3	0	2.3	.5	1.8	.4	1.4	1.2	.2
Total	$261.3	$ 39.2	$300.5	$ 30.3	$270.2	$ 65.6	$204.6	$ 76.7	$127.9	$110.0	$ 17.9

FY 1984 Renewable Energy Obligations

(Dollars in millions)

				First Quarter		Second Quarter		Third Quarter		Fourth Quarter	
	FY 1984 Appropriation	Unobligated Carryover and Repro-gramming	Total Obligation Authority	Oligations	Unobligated Balance	Added Obligations	Unobligated Balance	Added Obligations	Unobligated Balance	Added Obligations	Unobligated Balance
Solar Energy											
Buildings	$ 16.4	$+ .7	$ 17.1	$ 1.0	$ 16.1	$ 3.5	$ 12.6				
Photovoltaics	50.4	+ .8	51.2	23.4	27.8	18.0	9.8				
Solar Thermal	43.8	+ 4.2	48.0	16.0	32.0	6.8	25.2				
Biofuels	28.4		28.4	.6	27.8	14.7	13.1				
Wind	26.4		26.4	21.5	4.9	.2	4.7				
Ocean	5.5	+ 1.8	7.3	.3	7.0	3.2	3.8				
International	.5	+ .1	.6	0	.6	-1.0	1.6				
Tech. Transfer	3.2	+ .3	3.5	0	3.5	2.4	1.1				
Prog. Support	.9		.9	.1	.8	0	.8				
Prog. Direction	6.0	+ 1.1	7.1	1.2	5.9	2.7	3.2				
Reserve Acct	0.0	+ .2	.2	-.8	1.0	.1	.9				
Total Solar Energy	181.5*	9.2**	190.7	63.3	127.4	50.6	76.8				
Geothermal											
Geopressure	5.0	0	5.0	2.0	3.0	1.6	1.4				
Geo. Tech. Dev.	21.5	+ 1.1	22.6	11.7	10.9	2.3	8.6				
Hydrothermal	2.0	+ 2.6	4.6	0	4.6	2.0	2.6				
Prog. Direction	1.0	+ .4	1.4	.2	1.2	.2	1.0				
Total Geothermal	$ 29.5	$ 4.1	33.6	13.9	19.7	6.1	13.6				
Hydropower	.8	.2	1.0	0	1.0	.3	.7				
Total	$211.8	$ 13.5	$225.3	$ 77.2	$148.1	$ 57.0	$ 91.1				

*$181.5M total includes $3M supplemental for Solar Thermal

**$7.052M unobligated carryover is proposed for defferal

1983 CONSERVATION OBLIGATIONS

				FIRST QUARTER		SECOND QUARTER		THIRD QUARTER		FOURTH QUARTER	
PROGRAMS	FY 1983 APPROPRIATION	UNOBLIGATED CARRYOVER – REDUCTIONS	T.O.A.	OBLIGATIONS	UNOBLIGATED BALANCE	ADDED OBLIGATIONS	UNOBLIGATED BALANCE	ADDED OBLIGATIONS	UNOBLIGATED BALANCE	ADDED OBLIGATIONS	UNOBLIGATED BALANCE
Building Energy R&D	39.1	2.8	41.9	4.3	37.6	7.2	30.4	6.3	24.1	16.5	7.6
Industrial Programs	27.9	8.8	36.7	2.1	34.6	2.7	31.9	10.4	21.5	8.4	13.1
Vehicle & Engine R&D	53.9	5.6	59.5	10.4	49.1	32.5	16.6	7.6	9.0	5.8	3.2
State & Local Assistance	383.6	25.2	408.8	.4	408.4	-1.4	409.8	148.0	261.8	235.2	26.6
Multi-Sector	12.7	1.4	14.1	2.5	11.6	2.4	9.2	5.1	4.1	.9	3.2
Electric Energy/ Energy Storage Systems	42.9	1.6	44.5	.2	44.3	13.3	31.0	21.7	9.3	5.9	3.4
TOTAL CONSERVATION	560.1	45.4	605.5	19.9	585.6	56.7	528.9	199.1	329.8	272.7	57.1

1984 CONSERVATION OBLIGATIONS

PROGRAMS	FY 1984 APPROPRIATION	UNOBLIGATED CARRYOVER	T.O.A.	FIRST QUARTER		SECOND QUARTER		THIRD QUARTER		FORTH QUARTER	
				OBLIGATIONS	UNOBLIGATED BALANCE	ADDED OBLIGATIONS	UNOBLIGATED BALANCE	ADDED OBLIGATIONS	UNOBLIGATED BALANCE	ADDED OBLIGATIONS	UNOBLIGATED BALANCE
Building Energy R&D	37.4	7.6	45.0	2.0	43.0	12.1	30.9				
Industrial Programs	33.7	13.1	46.8	1.2	45.6	10.4	35.2				
Vehicle & Engine R&D	65.0	3.2	68.2	34.5	33.7	5.8	27.9				
State & Local Assistance	280.2	26.6	306.8	-.7	307.5	4.9	302.6				
Multi-Sector	12.8	3.2	16.0	1.8	14.2	5.2	9.0				
Electric Energy/ Energy Storage Systems	44.2	3.4	47.6	9.7	37.9	17.9	20.0				
TOTAL CONSERVATION	473.3	57.1	530.4	48.5	481.9	56.3	425.6				

QUESTIONS FROM SENATOR CARL LEVIN

Management Initiatives

Question 8: You have listed in your Conservation budget savings from "Management Initiatives" totaling $5 million. What specific management initiatives comprise this $8 million savings?

Answer: An estimated $8.0 million in management initiative savings in the Energy Conservation account reflect deobligation of multi-year funds. Deobligations may occur due to contract close-out, contractor defaults, or other instances of contractual dollar reductions, such as cost disallowances based on audit results. Such deobligations are being reported and evaluated to determine whether the funding should be retained in the program area where it was orginally appropriated. Where there is no compelling reason to retain these funds in that program area, they will be used to offset budget authority in FY 1985.

Question 9: When will you know if you have achieved these management initiatives?

Answer: The $8.0 in management initiative savings is comprised of $4.0 million to be obtained from deobligations in FY 1984 and an additional $4.0 million to be obtained from deobligations in FY 1985. Therefore, it is estimated that sufficient data will be available by the 3rd quarter FY 1985 to determine if savings targets will be achieved.

QUESTIONS FROM SENATOR CARL LEVIN

Management Initiatives

Question 10: What will you do if you don't achieve these savings?

Answer: The FY 1985 budget was formulated on the assumption that $8.0 million from 1984 and 1985 would be available by the end of FY 1985. The Appropriation language contained in the Department's 1985 request is drafted in a manner that automatically adjust the appropriation level to account for the actual level of management savings. For example, if less than $8 million in savings is realized, then the appropriation level would be adjusted upward by the amount of the shortfall. Under all circumstances, the program level would be unaffected.

QUESTIONS FROM SENATOR LEVIN

ELECTRIC VEHICLE PROGRAM

Question 11: I understand that the electric vehicle program or at least a portion of it was transferred from the Jet Propulsion Labs to the Idaho facility, is that correct?

Why was this transfer done?

What did it cost to transfer the program?

Answer: The dynamometer test facility that was being used at the Jet Propulsion Laboratory (JPL) for vehicle and battery testing is in the process of being transferred to the Idaho National Engineering Laboratory (INEL), a Department of Energy facility. It is expected that INEL will be operational for electric vehicle testing in August 1984.

In FY 1983 JPL informed DOE that it was going to be necessary for them to cut back their participation in some energy programs so that they may direct their facilities and manpower toward an expected increase in NASA and Department of Defense programs, which they determined were more directly related to their primary mission. Among the activities JPL chose to discontinue was the electric and hybrid vehicle dynamometer testing, which was occupying facility areas that they needed for their expanded NASA activities.

The cost in FY 1984 for the transfer of the test program to INEL is $850,000.

QUESTIONS FROM SENATOR LEVIN

ENERGY RESEARCH AND DEVELOPMENT

Question 12.: What is the proposed number of personnel for the energy conservation programs? How does this compare to the number of persons required in those programs under current law?

Answer: Section 303 of Public Law 97-257, the Supplemental Appropriations Act of 1982, requires the Department to maintain not less than 352 full-time permanent Federal employees for those positions of the Office of the Assistant Secretary for Conservation and Renewable Energy which are funded by Interior Appropriations, with not less than 154, 180 and 18 employees assigned to conservation R&D, State and Local Assistance Programs and other, respectively. The proposed number of personnel in the FY 1985 Congressional request is 298 with 128, 150 and 20 employees assigned to conservation R&D, State and Local Assistance, and other, respectively.

QUESTIONS FROM SENATOR LEVIN

FELLOWSHIPS

Question 13: Your budget request shows a significant number of fellowships being created as new initiatives in the buildings program and in other areas as well. How much money is proposed to be spent for fellowships?

Answer: A total of $5 million is contained in the FY 1985 budget request for Energy Conservation to cover a fellowship program - a new initiative designed to enhance conservation research efforts and to create a mechanism by which technology results from the National Laboratories will be infused into the related portions of industry and university research.

Within each of the end-use programs of Conservation - Buildings and Community Systems, Transportation, and Industrial Energy Conservation, selected projects will be identified in the National Laboratories which would benefit from having industrial or university research personnel working on them. Fellows would be given grants to cover one-to-two year sabbaticals to work on the projects in the National Laboratories, thus acquiring knowledge of the National Laboratory and experience with advanced equipment, some of which is available only in the National Laboratories. The fellowship program will benefit the laboratories and the industrial and university research communities by increasing communication of information, needs, and research results.

QUESTIONS FROM SENATOR CARL LEVIN

Question 14: In December 10, 1981 Mr. Tenny Johnson, General Counsel of DOE testified before the subcommittee on Energy, Nuclear Non-proliferation, and Govt. Processes of the Committee on Governmental Affairs that 900 cases remained to be completed. DOE's goal was to complete all of the audits by the end of 1982.

It is now 1984:
- Have the audits been completed?
- (If not) How many audits remain to be completed?
- How many cases have final consent orders?

Answer: As of April 30, 1984, 58 field audits remained to be completed by the ERA audit staff. In 35 of those audits, completion is being delayed by the firms' resistance to subpoena compliance, but the majority of the other 23 field audits are in the final stages of completion. (In 153 other cases the field audits are complete and the ERA is reviewing the preliminary findings in each case to determine whether and to what extent formal enforcement action should be initiated; settlement discussions have been conducted on many of those 153 cases, and at least 11 firms have come to a tentative but not yet final agreement.)

From October 1, 1981, through May 31, 1984, ERA had settled 445 cases for a total of $492,585,945. As outlined above, a total of 211 cases either await audit completion or ERA's determination as to formal action. Most of the other 259 cases have been the subject of formal enforcement actions, and some cases were closed for no violation.

Question 15: How many of these final consent orders allow installment payments?

Answer: 152 of the 445 Consent Orders involved installment payments.

QUESTIONS FROM SENATOR CARL LEVIN

Question 16: What is the scheduled income from these installment payment plans? In other words, how much money do we know will be coming in from final consent orders? (Please provide us with the scheduled receipts, by year, for the installment payments.)

Answer: The amount of actual receipts through May 31, 1984, and the scheduled future receipts through 1998 are listed below:

CONSENT ORDERS ISSUED SINCE 10-1-81 PROVIDING FOR INSTALLMENT PAYMENTS
STATUS AS OF MAY 31, 1984

TIME PERIOD	ACTUAL RECEIPTS (INCLUDING INTEREST) 10-1-81 - 5-31-84	SCHEDULED RECEIPT (INCLUDING EST. INTEREST) 6-1-84 - 12-31-98	TOTAL ATTRIBUTABLE TO INSTALLMENT CONSENT ORDERS
10/1/81 - 5/31/84	$50,740,467.77		
6/1/84 - 12/31/84		$ 12,027,650.11	
C.Y. 1985		$ 11,445,482.03	
C.Y. 1986		$ 7,101,611.79	
C.Y. 1987		$ 6,104,349.31	
C.Y. 1988		$ 5,689,757.67	
C.Y. 1989		$ 3,582,575.76	
C.Y. 1990		$ 3,046,575.77	
C.Y. 1991		$ 3,079,666.67	
C.Y. 1992		$ 3,073,666.67	
C.Y. 1993		$ 2,537,666.67	
C.Y. 1994		$ 2,531,666.67	
C.Y. 1995		$ 2,525,666.67	
C.Y. 1996		$ 2,519,666.67	
C.Y. 1997		$ 2,466,666.67	
C.Y. 1998		$ 2,466,666.62	
TOTALS	$50,740,467.77	$ 70,199,335.75	$120,939,803.52

QUESTIONS FROM SENATOR CARL LEVIN

Question 17: How many of the consent order receipts are delinquent?

Answer: 22 of the 152 installment term Consent Orders issued since October 1, 1981 are delinquent. Of the $50,959,008 scheduled to have been paid through May 31, 1984 on the 152 accounts, $50,740,467 has been collected and $218,541 is currently delinquent. $100,000 of that amount is owed by one firm which has filed for bankruptcy. The delinquency amounts involved in the other 21 cases range from $85 to $30,441, and average $5,600; collection efforts have been initiated on all of these accounts, and some have been referred to the Department of Justice for collection.

QUESTION FROM SENATOR CARL LEVIN

Question 18: What is the penalty for delinquent payment?

Answer: The penalty for delinquent payment varies in accordance with the degree of delinquency and the specific terms which were negotiated into the Consent Orders. Many of the Consent Orders provided for higher interest rates to be applied to past due amounts and some even provided for acceleration of the entire balance in the event of late payment. If the preliminary collection efforts by the ERA and/or the Department's Office of General Counsel (including compounded interest), the matter is referred to the Department of Justice which then attempts, through the Federal Courts, to obtain a judgment for the delinquent amounts and in some cases a civil penalty for failure to comply with a valid Order. However, less severe actions may be invoked when the dollar amount of the deliquency is small or the degree of tardiness is slight.

QUESTIONS FROM SENATOR CARL LEVIN

DOE'S BUDGET IN FY' 85 CONSERVATION AND RENEWABLE ENERGY

Question 19. According to a February 7, 1984 decision by the Comptroller General of the United States the DOE has erroneously deposited oil overcharge funds directly into the Treasury as miscellaneous receipts. DOE deposited these funds directly into the Treasury without first attempting to find claimants through the mandatory Subpart V procedures.

- What is the total dollar amount that has been erroneously deposited as miscelleaneous receipts in the general Treasury?

- What assurance do we have that this error will not reoccur?

Answer: The General Counsel of the Department has concluded, in Ruling 1984-1, that the Comptroller General erred in his interpretation of DOE's regulations as requiring the use of Subpart V procedures. Thus DOE's payments into the Treasury were not erroneous and it is not necessary for the Department to take any further action with respect to this matter. The Secretary has conveyed that conclusion to the Congress in accordance with section 236 of the Legislative Reorganization Act of 1970, 31 U.S.C. 720. A copy of that Ruling and the Secretary's transmittal is attached.

THE SECRETARY OF ENERGY
WASHINGTON, D.C. 20585

June 8, 1984

Honorable Mark O. Hatfield
Chairman, Committee on
Appropriations
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On February 7, 1984, the Comptroller General of the United States sent to the Department a copy of his decision, B-210176, regarding funds paid into the United States Treasury pursuant to consent orders settling alleged violations of the petroleum price and allocation regulations. The Comptroller General has construed statutes and regulations administered by this Department in a manner which had led him to consider these payments to have been made erroneously, and he makes recommendations for what he believes to be proper corrective action. I am happy to provide the Department's response to the Comptroller General's decision in accordance with section 236 of the Legislation Reorganization Act of 1970, 31 U.S.C. § 720.

The February 7, 1984 decision reiterates the Comptroller General's view, stated in three prior opinions, that the Department lacks authority to enter into consent orders which require the alleged violator to make restitutionary payments directly to the United States Treasury. According to the Comptroller General, the statutes and regulations administered by DOE instead require use of the agency's special refund (or Subpart V) procedures, 10 C.F.R. §§ 205.280-205.288, in each case where DOE enforcement officials cannot readily determine who was injured and in what amount. B-210176 at 3; 62 Comp. Gen. 379, 385-86 (1983); 60 Comp. Gen. 15, 25-26 (1980); see also B-2100170 at 4-5 (1981). This is the basis for the Comptroller General's conclusion that payments to the Treasury made pursuant to consent orders were "erroneously deposited" within the meaning of 31 U.S.C. § 1322(b)(2) and thus subject to retrieval.

Based on this legal predicate, the Comptroller General proposes that the DOE: (1) compile a list of all consent orders containing Treasury payment provisions, including the names of the consenting firms and "known major purchasers from them," B-210176 at 7; (2) publish the list as a notice in the *Federal Register* and invite the filing of claims; (3) refer claims to the Office of Hearings and Appeals for Subpart V proceedings; and (4) order the retrieval and refund of monies to purchasers who can establish a claim in Subpart V proceedings.

The Department of Energy does not accept the Comptroller General's recommendations because their legal predicate -- that Treasury payment remedies are unlawful -- is incorrect. The Comptroller General's legal analysis is at odds with judicial decisions construing the relevant statutes and conflicts with longstanding agency interpretations and practices. The Emergency Petroleum Allocation Act, 15 U.S.C. § 751 *et seq.*, and the Economic Stabilization Act, 12 U.S.C. § 1904 *note*, as construed by the courts, and the regulations promulgated by DOE, permit the agency to use forms of indirect restitution in consent orders, including Treasury payment remedies, when DOE enforcement officials have determined that it is infeasible to identify the persons who were likely to have been injured and to ascertain the amount of their injuries. *See, e.g., Getty Oil Company v. DOE*, 569 F. Supp. 1204 (D. Del. 1983), *appealed on other grounds*, No. 3-37 (TECA Oct. 19, 1983); *United States v. Exxon Corp.*, 516 F. Supp. 816 (D.D.C. 1983), *appeal docketed*, No. DC-91 (TECA June 22, 1983); *Pennzoil Company v. DOE*, 4 Energy Mgmt. (CCH) ¶ 26,415 (D. Del.), *aff'd on other grounds sub nom. Cities Service Company v. DOE*, 715 F.2d 572 (TECA 1983). The Department's interpretation on the remedy issues raised by the Comptroller General is more fully delineated in Ruling 1984-1, "Restitutionary Authority Available to the Department of Energy Under the Statutes and Regulations It Administers," which is attached as Appendix A and is incorporated by reference.

Since the Department does not accept the Comptroller General's view that the DOE exceeded its legal authority, we do not believe that amounts paid into the Treasury pursuant to consent orders were "erroneously deposited." Accordingly, the Department does not plan to implement the Comptroller General's recommendations.

Insofar as the Department's current practice is to use Subpart V as the primary vehicle for distributing consent order funds, the Department has no present intention of entering into additional consent orders which require an alleged violator to make a direct refund to miscellaneous receipts of the United States Treasury.

Sincerely,

Donald Paul Hodel

DONALD PAUL HODEL

Enclosure

cc w/enclosure:
Honorable John C. Stennis
Ranking Minority Member
Committee on Appropriations
United States Senate
Washington, D.C. 20510

The order is effective under the Agricultural Marketing Agreement Act of 1937, as amended (7 U.S.C. 601–674). The action is based upon recommendations and information submitted by the Lemon Administrative Committee and upon other available information. It is hereby found that this action will tend to effectuate the declared policy of the Act.

This action is consistent with the marketing policy currently in effect. The committee met publicly on May 22, 1984, at Los Angeles, California, to consider the current and prospective conditions of supply and demand and recommended a quantity of lemons deemed advisable to be handled during the specified week. The committee reports that lemon demand is good.

It is further found that it is impracticable and contrary to the public interest to give preliminary notice, engage in public rulemaking, and postpone the effective date until 30 days after publication in the **Federal Register** (5 U.S.C. 553), because of insufficient time between the date when information became available upon which this regulation is based and the effective date necessary to effectuate the declared purposes of the Act. Interested persons were given an opportunity to submit information and views on the regulation at an open meeting. It is necessary to effectuate the declared purposes of the Act to make these regulatory provisions effective as specified, and handlers have been apprised of such provisions and the effective time.

List of Subjects in 7 CFR Part 910

Marketing agreements and orders, California, Arizona, Lemons.

PART 910—[AMENDED]

Section 910.785 is added as follows:

§ 910.785 Lemon Regulation 435.

The quantity of lemons grown in California and Arizona which may be handled during the period May 27, 1984, through June 2, 1984, is established at 300,000 cartons.

(Secs. 1–19, 48 Stat. 31, as amended; 7 U.S.C. 601–674)

Dated: May 23, 1984.

Thomas R. Clark,

Deputy Director, Fruit and Vegetable Division, Agricultural Marketing Service.

[FR Doc. 84-14258 Filed 5-24-84; 8:45 am]

BILLING CODE 3410-02-M

DEPARTMENT OF JUSTICE

Immigration and Naturalization Service

8 CFR Part 223

Reentry Permits

AGENCY: Immigration and Naturalization Service, Justice.

ACTION: Final rule.

SUMMARY: This final rule removes § 223.4 concerning revalidation of reentry permits issued after December 29, 1980. Since the enactment of Pub. L. 97–116, all reentry permits, with the exception of restricted permits, have been valid for a period of two years from the date of issuance and cannot be renewed. As of December 29, 1983, no reentry permits exist requiring revalidation. This section is removed because it is no longer applicable.

EFFECTIVE DATE: May 25, 1984.

FOR FURTHER INFORMATION CONTACT:

For General Information: Loretta J. Shogren, Director, Policy Directives and Instructions, Immigration and Naturalization Service, 425 I Street, NW., Washington, D.C. 20536, Telephone: (202) 633–3048

For Specific Information: F. Gerard Heinauer, Immigration Examiner, Immigration and Naturalization Service, 425 I Street NW., Washington, D.C. 20536, Telephone: (202) 633–5014

SUPPLEMENTARY INFORMATION: On December 29, 1981, Pub. L. 97–116 (95 Stat. 1611) was enacted, extending the period of validity for the issuance of a reentry permit to two years unless otherwise restricted. The Service, by regulation (47 FR 12129), declared all reentry permits issued after December 29, 1980 as revalidated for a period of two years from the original date of issue, unless the permit was restricted for cause at the date of issuance. Since December 29, 1981 all reentry permits, with the exception of restricted permits, have been issued for a period of two years. Accordingly, as of December 29, 1983, there no longer exist a need for revalidation under 8 CFR 223.4.

Compliance with 5 U.S.C. 553 as to notice of proposed rulemaking and delayed effective date is unnecessary because this rule merely removes a provision that is outdated.

In accordance with 5 U.S.C. 605(b), the Commissioner of Immigration and Naturalization certifies that the rule, if promulgated, will not have a significant impact on a substantial number of small entities.

This order is not a major rule within the definition of section 1(b) of E.O. 12291.

List of Subjects in 8 CFR Part 223

Administrative practice and procedure, Aliens, Reentry permits.

PART 223—REENTRY PERMITS

Accordingly, Chapter 1 of Title 8 of the Code of Federal Regulations is amended as follows:

§ 223.4 [Removed]

Section 223.4 is removed.

(Sec. 223 of the Immigration and Nationality Act, as amended (8 U.S.C. 1203))

Dated: May 10, 1984.

Andrew J. Carmichael, Jr.,

Associate Commissioner, Examinations Immigration and Naturalization Service.

[FR Doc. 84-14030 Filed 5-24-84; 8:45 am]

BILLING CODE 4410-10-M

DEPARTMENT OF ENERGY

10 CFR Ch. II

Administrative Procedures and Sanctions; Restitutionary Authority Available to the Department Under the Statutes and Regulations It Administers

AGENCY: Department of Energy.

ACTION: Ruling.

SUMMARY: The Department of Energy ("DOE") Office of General Counsel issues the appended Ruling pursuant to 10 CFR 205.150 to clarify the scope of its remedial authority under the Emergency Petroleum Allocation Act, 15 U.S.C. 751 *et seq.*, and to address certain opinions that the Comptroller General of the United States has offered on the subject. A written comment on or objection to the appended Ruling may be filed at anytime with the DOE Office of General Counsel pursuant to the provisions of 10 CFR 205.158.

FOR FURTHER INFORMATION CONTACT: Lona L. Feldman, Office of General Counsel, Department of Energy, 1000 Independence Avenue SW., Room 6B144, Forrestal Building, Washington, D.C. 20585, (202) 252–9507.

Issued in Washington, D.C.

Dated May 22, 1984.

William H. Mellor III,

Deputy General Counsel Regulation.

Title 10 of the Code of Federal Regulations is hereby amended by adding Ruling 1984–1 to the Appendix to subchapter A to read as follows:

Ruling 1984-1—Restitutionary Authority Available to the Department of Energy Under the Statutes and Regulations It Administers

As the enforcement program under the Emergency Petroleum Allocation Act ("EPAA"), 15 U.S.C. 751 *et seq.*, approaches its conclusion, remedy issues involving transactions that occurred during the period of controls have become more prominent. The Comptroller General of the United States has rendered several opinions construing statutes and regulations administered by the Department of Energy ("DOE") in which he has raised questions about the Department's exercise of its remedial authority. These views have also been presented to the various courts in connection with remedy-related litigation. The Department has not previously formulated a comprehensive delineation of the remedies authorized by its regulations and the EPAA. DOE has, instead, addressed these matters on a case by case basis. Since certain enforcement matters stemming from the period of controls remain to be concluded, those affected by remedies in such matters would be aided by an authoritative interpretation of the statutes and regulations bearing on this subject.

This ruling sets forth the Department of Energy's interpretation of the scope of its remedial authority under the EPAA and regulations promulgated by the Department and addresses specifically certain opinions that the Comptroller General has offered on this subject.

I. Background

During the course of the EPAA enforcement program, DOE has collected hundreds of millions of dollars from firms through orders, settlements and judgments which resolved alleged violations of the petroleum price and allocation regulations. In order to benefit those who were economically injured by the alleged or adjudicated violations, DOE has utilized a number of different restitutionary remedies.

For example, prior to decontrol, Exec. Order 12287, 46 FR 9909 (Jan. 30, 1981), many DOE orders provided refunds to overcharged direct purchasers who were not end users, since under price controls such payments could benefit consumers by reducing the product costs the direct purchasers were permitted to pass on. *See generally* 10 CFR 212.83(c)(2) (refiner price rule); 10 CFR 212.93(c) (reseller price rule). Since decontrol, refunds to first purchasers that are not end users are rarely ordered because such payments are no longer an effective means of directing disgorged sums to injured downstream customers. Price rollbacks were also rendered ineffective by decontrol since there are no longer regulated prices from which rollbacks can be instituted.

Until recently, DOE's Economic Regulatory Administration ("ERA") used several different types of remedies in its consent orders. Some consent orders provided for direct disbursement to particular purchasers; some provided for various forms of "indirect restitution" (such as payments to the states and deposits of funds to the United States Treasury), where tracing the effects of overcharges to identifiable injured purchasers was infeasible; and other consent orders provided for distribution by DOE through, *inter alia*, the agency's special refund or "Subpart V" procedures, 10 CFR 205.280–205.288. DOE's current practice is to use Subpart V as the primary vehicle for distributing consent order funds.

The courts, in ordering or affirming a variety of remedies, have almost uniformly observed the great breadth of the statutory concept of restitution and approved DOE's interpretation of its remedial authority. *See, e.g., Getty Oil Company* v. *DOE*, 569 F. Supp. 1204 (D. Del. 1983), *appealed on other grounds*, No. 3–37 (TECA Oct. 19, 1983); *United States* v. *Exxon Corp.*, 516 F. Supp. 816 (D.D.C. 1983), *appeal docketed*, No. DC–91 (TECA June 22, 1983); *Pennzoil Company* v. *DOE*, 4 Energy Mgmt. (CCH) ¶26,415 (D. Del.), *aff'd on other grounds sub nom. Cities Service Company* v. *DOE*, 715 F. 2d 572 (TECA 1983). The Comptroller General of the United States, however, has offered a more narrow view, stating, in four opinions, that DOE's own regulations and the relevant statutes mandate use of Subpart V in each case where the identity of injured purchasers and the amount of their injuries cannot be readily ascertained. *See* Comp. Gen. decision B–210176, Feb. 7, 1984; 62 Comp. Gen. 379 (1983); Comp. Gen. Opinion B–200170, April 1, 1981; 60 Comp. Gen. 15 (1980).

Under the Legislative Reorganization Act of 1970, 31 U.S.C. 720, the DOE is required to submit a formal response to the latest Comptroller General opinion. Moreover, the Temporary Emergency Court of Appeals has recently expressed an interest in the Comptroller General's February 7, 1984 opinion in one case, *Hodel* v. *Hunt*, No. 5–101, slip. op. (TECA April 24, 1984), and the Comptroller General's opinions have been presented to the courts in several other proceedings. Important remedy issues are at stake in these cases, and the courts and the public would be aided by a clear and coherent statement on DOE's remedial authority from DOE, the agency charged with administering and enforcing the relevant statutes and regulations. Under these circumstances, the DOE is issuing this ruling to set forth its interpretation, and to address the Comptroller General's views, concerning the scope of the Department's remedial authority.

For the reasons stated in this ruling, the DOE concludes that the statutes and regulations it administers permit use of the following mechanisms where appropriate to remedy the effects of violations or alleged violations of the price and allocation regulations: payments to direct purchasers and downstream customers; use of the agency's special refund procedures (10 CFR Part 205, Subpart V); payments to the United States Treasury; payments to the states; and such other restitutionary actions as are appropriate in the circumstances of a given matter.

II. DOE's Regulations on Remedies

The Comptroller General contends that DOE regulations require resort to Subpart V procedures whenever injured persons cannot be readily identified or the extent of their injuries cannot be reasonably determined, and that, under these circumstances, DOE may not enter into consent orders unless the funds disgorged are to be distributed pursuant to Subpart V. B–210176 at 3; 62 Comp. Gen. 379, 385–86; 60 Gen. 15, 25–26; *see also* B–200170, at 4–5. The Comptroller General is incorrect in his reading of the regulations promulgated by this Department, as the following textual, historical and structural analysis indicates.

DOE has adopted two major regulatory provisions of remedies: the general remedies regulation, 10 CFR 205.1991, and the special refund (or Subpart V) procedures, 10 CFR 205.280 *et seq.* The general remedies regulation specifies a broad and non-exclusive array of remedies DOE may utilize:

> A Remedial Order * * * or a Consent Order may require the person to whom it is directed to roll back prices, to make refunds equal to the amount (plus interest) charged in excess of those amounts permitted under DOE regulations, * * * and to take such action as the DOE determines is necessary to eliminate or to compensate for the effects of a violation * * *. Such action may include a direction to the person to whom the Order is issued to establish an escrow account or take other measures to make refunds directly to the purchasers of the products involved, notwithstanding the fact that those purchasers obtained such products from an intermediate distributor of such person's

> products * * *. In cases where purchasers cannot be reasonably identified or paid or where the amount of each purchaser's overcharge is incapable of reasonable determination, the DOE may refund the amounts received in such cases directly to the Treasury of the United States on behalf of such purchasers.

10 CFR 205.199I, 44 FR 7922 (Feb. 7, 1979).

This regulation has a long history in the price control programs administered by DOE and its predecessor agencies. In regulations promulgated under the Economic Stabilization Act of 1970 ("ESA"), 12 U.S.C. 1904 note, the Cost of Living Council privided for administrative remedial orders, which were defined as:

> An order requiring a person to cease a violation or to take action *to eliminate or to compensate for the effects of a violation, or both*, or which imposes other sanctions.

6 CFR 155.81(b); 38 FR 21981, 21985 (Aug. 15, 1973) (emphasis added). DOE and its predecessors continued to construe their remedial authority very broadly in regulations issued under the EPAA. *See* 10 CFR 205.86, 39 FR 1924 (Jan. 15, 1974); 10 CFR 205.194, 39 FR 32262 (Sept. 5, 1974); 10 CFR 205.195, 40 FR 40141 (Sept. 2, 1975). In a February 1979 amendment to the regulations, DOE specifically recognized that overcharge funds may be paid directly to the United States Treasury where it is infeasible to determine who was injured or in what amount. 10 CFR 205.199I(a), 44 FR 7922 (Feb. 7, 1979).

In February 1979, DOE also promulgated the Subpart V regulations. 10 CFR 205.280 *et seq*, 44 FR 8562 (Feb. 9, 1979). Under these procedures, when requested to do so by a DOE enforcement official, DOE's Office of Hearings and Appeals ("OHA") may determine an equitable distribution of petroleum violation funds obtained by DOE through a consent order or remdial order. *See* 10 CFR 205.281, 205.282. After a Subpart V proceeding is initiated, OHA establishes standards for the distribution of refunds to potentially injured purchasers, pursuant to which purchasers may obtain refunds upon filing claims which satisfy OHA's standards. 10 CFR 205.282, 205.284(d). OHA then effects some form of indirect restitution with funds remaining after successful claimants have been paid. 10 CFR 205.287(c).

Under DOE regulations, the decision to initiate Subpart V refund procedures is a matter within the discretion of agency enforcement officials:

> At any time after the issuance of the Remedial Order * * * or a Consent Order, the Special Counsel of the Department of Energy, the ERA Office of Enforcement or any other enforcement official of the Department of Energy *may* file with the Office of Hearings and Appeals a Petition for the Implementation of Special Refund Procedures.

10 CFR 205.281(a) (emphasis added). In contrast to the permissive "may" in § 205.281(a), the regulations use the mandatory "shall" in describing the requirements for the contents of a petition:

> The Petition *shall* state that the person filing it has been unable readily either to identify the persons who are entitled to refunds to be remitted pursuant to a Remedial Order or a Consent Order or to ascertain the amounts of refunds that such persons are entitled to receive. The Petition *shall request* that the Office of Hearings and Appeals institute appropriate proceedings under this subpart * * *.

10 CFR 205.281(b) (emphasis added). DOE's use of the permissive "may" in § 205.281, juxtaposed with the mandatory "shall," demonstrates that ERA's initiation of Subpart V procedures is discretionary. *E.g., Koch Refining Company* v. *DOE*, 658 F.2d 799, 803–04 (TECA 1981). The fact that an enforcement official must "request" that OHA entertain a petition also emphasizes the discretionary nature of such a proceeding.

The "purpose and scope" provision of the Subbpart V regulations sets forth the appropriate circumstances for use of the Subpart V procedures:

> This subpart establishes special procedures pursuant to which refunds *may* be made to injured persons in order to remedy the effects of a violation of the regulations of the Department of Energy. This subpart *shall be applicable* to those situations in which the Department of Energy is unable to readily identify persons who are entitled to refunds specified in a Remedial Order * * * or a Consent Order, or to readily ascertain the amounts that such persons are entitled to receive.

10 CFR 205.280 (emphasis added). The Comptroller General has incorrectly concluded that Subpart V is mandatory, because he has misinterpreted the phrase "shall be *applicable*" in § 205.280 to mean "must be *applied*" or "must be *used*" and because he has ignored § 205.281 altogether. Section 205.280, read in conjunction with § 205.281, indicates that an ERA enforcement official has discretion whether to initiate a Subpart V proceeding in "applicable * * * situations," *i.e.*, where he has been unable to readily identify injured persons or to ascertain the extent of their injuries.[1]

The Comptroller General's interpretation of Subpart V is also incorrect because it ignores the general remedies regulation, § 205.199I, and the consent order regulation, § 205.199J. These provisions permit DOE in a Consent Order or Remedial Order to "require the person to whom it is directed * * * to make refunds * * * *and to take such other actions as the DOE determines is necessary to eliminate or to compensate for the effects of a violation* * * *." 10 CFR 205.199I(a) (emphasis added). Moreover, direct refunds to the Treasury are specifically authorized "where purchasers cannot be reasonably identified or paid or where the amount of each purchaser's overcharge is incapable of reasonable determination." *Id.* Finally, the regulations explicitly provide that a "Consent Order * * * may require one or more of the remedies authorized by § 205.199I." 10 CFR 205.199J(b).

Since § 205.199I and § 205.199J authorize Treasury payments and other remedies where injured purchasers cannot be reasonably ascertained, the Comptroller General's interpretation of Subpart V as mandatory is simply at odds with the plain meaning of these other remedial provisions. The Comptroller General's opinion necessarily assumes that DOE repealed the general remedy regulation by implication when the agency promulgated the Subpart V regulations. However, 10 CFR 205.199I had been repromulgated only *two days* before the Subpart V regulations were issued, (*compare* 10 CFR 205.199I, 44 FR 7922 (Feb. 7, 1979), *with* 10 CFR 205.280 *et seq.*, 44 FR 8562 (Feb. 9, 1979)), and the general remedies regulation had been revised specifically to acknowledge DOE's authority to remit overcharge funds directly to the U.S. Treasury in appropriate cases. Regulatory constructions requiring implied repeals of agency rules are disfavored. *See, e.g.*, *Regional Rail Reorganization Act Cases*, 419 U.S. 102, 133 (1974); *Morton* v. *Mancari*, 417 U.S. 535, 551 (1974). Here, the contemporaneous publication of § 205.199I and Subpart V combined with the precatory and broad language of the regulations, and the lack of any regulatory history which suggests that DOE intended to repeal essential provisions of its remedy and consent order regulations when it created Subpart V all lead to the conclusion that Subpart V was promulgated to provide an additional remedial mechanism for DOE enforcement officials, not an exclusive one.[2] Thus, consent orders and remedial orders may contain remedies authorized by § 205.1991; use of Subpart V is discretionary. Accordingly, DOE's regulations permit the agency to enter into consent orders and issue remedial orders providing for payments to the Treasury and other forms of indirect restitution in appropriate cases.

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[1] The Comptroller General has also placed mistaken reliance on the fact that the final version of § 205.280 does not contain the proposed regulation's prefatory language—"As a general rule." B-200170 at 4 *quoting* 43 FR 53256, 53257 (Nov. 15, 1978). The above-quoted language was superfluous, as evidenced by the fact that the preamble to the final rule described explicitly the changes to the proposal made by the final rule, but contained no mention at all of this particular deletion. To the extent the deletion has any import, it indicates that Subpart V should be used *only* where enforcement officials cannot precisely determine the impact of alleged violations on particular purchasers; it does not mean that Subpart V must be used in all cases where it may be used.

III. DOE's Statutory Authority To Effect Restitution

Section 209 of the ESA, 12 U.S.C. 1904 note, as incorporated by Section 5(a)(1) of the EPAA, 15 U.S.C. 754(a)(1), specifically authorizes a court, in a judicial enforcement action, to order a violator to make restitution of overcharges.[3] The courts have held that DOE also has broad remedial authority that includes the ability to require restitution by administrative order. *Sauder* v. *DOE*, 648 F.2d 1341 (TECA 1981); *Bonray Oil Co.* v. *DOE*, 601 F.2d 1191 (TECA 1979), *aff'g on basis of district court opinion*, 472 F. Supp. 899 (W.D. Okla. 1978).

The Comptroller General has said that DOE's restitutionary authority restricts DOE to the use of Subpart V whenever the Department cannot readily determine the impact of alleged overcharges on injured parties. The Comptroller General has also asserted that after all claims have been paid in Subpart V, DOE must deposit the remaining funds in the U.S. Treasury, and that any other form of "indirect restitution" is impermissible.

In contrast, the courts have regularly found DOE's remedial powers to be expansive because of the broad enforcement and regulatory authority conferred on the agency and its predecessors. *Sauder* v. *DOE, supra; Bonray Oil Co.* v. *DOE, supra; see also University of Southern California* v. *Cost of Living Council*, 472 F.2d 1065 (TECA 1972), *cert. denied*, 410 U.S. 928 (1973).[4] In *Bonray Oil Co.* v. *DOE, supra*, the Temporary Emergency Court of Appeals ("TECA") upheld DOE's authority to order restitution because TECA found restitution to be rationally related to the statutory goal of regulating petroleum prices at "equitable" levels. EPAA § 4(b)(1)(*f*), 15 U.S.C. 753. The court held that section 209 of the ESA, which authorizes a court to order restitution, was not intended to prevent the agency from requiring that remedy. 472 F. Supp. at 903.[5] The court concluded that the scope of DOE's remedial authority must be measured by "the broad purposes of the Congressional mandate in both the ESA and EPAA." 472 F. Supp. at 904.[6]

This expansive interpretation was reaffirmed by TECA in *Sauder* v. *DOE, supra*, where the court expressed its view that "restitution" is:

> * * * A remedy by which a defendant is made to disgorge ill-gotten gains or to restore the status quo or to achieve both objectives. * * * There is no indication, however, that [Section 209 of the ESA] attempts to limit the power of the courts or the agency to restitution or to a particularly strict interpretation of restitution.

Sauder v. *DOE, supra*, 648 F.2d at 1348 (emphasis deleted and citations omitted). Relying on *Bonray*, TECA affirmed the agency's remedial determination since it was consistent with the statutory purpose of "set[ting] things right," 648 F.2d at 1348, and by eliminating the need for further complex proceedings, would prevent the Department from being "bogged down in an administrative quagmire." 648 F.2d at 1348, *quoting Tenneco Oil Co.* v. *FPC*, 442 F.2d 489, 497 (5th Cir. 1971).[7]

The scope of the court's authority to order "restitution" under section 209 of the ESA was subsequently addressed in *Citronelle-Mobile Gathering, Inc.* v. *Edwards*, 669 F.2d 717 (TECA), *cert. denied*, 103 S. Ct. 172 (1982). In the district court, the Government had sought an order requiring payment of overcharges into escrow for subsequent distribution to injured customers—some dozen of which were regulated utilities that had purchased most of the overpriced oil at issue. Any refund to the utilities would ordinarily be passed on to their customers under the usual rules of utility rate regulation. Departing from the remedy urged by the Government, the district court *sua sponte* determined that payment into the miscellaneous receipts of the U.S. Treasury was the more appropriate remedy. *Citronelle-Mobile Gathering, Inc.* v. *O'Leary*, 499 F. Supp. 871, 886 (S.D. Ala. 1980). Based upon the facts in that case, however, TECA rejected the Treasury payment remedy, and held that the Government must try (as it had sought to do before the district court) to trace the effects of the violations and to compensate the persons who bore the economic harm of the overcharge. TECA left open to DOE the discretion to fashion other remedies, such as payment to the Treasury, if making direct refunds to injured purchasers would be infeasible. 669 F.2d at 722–23; *id.* at 727 (Pointer, J., concurring and dissenting).[8]

In short, DOE must generally attempt to identify and provide refunds to injured purchasers (*i.e.*, provide direct restitution) where it is feasible. When tracing the effects of overcharges to identifiable purchasers is infeasible, however, indirect restitutionary measures are appropriate. *Getty Oil*

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[2] This conclusion is further supported by ERA's and OHA's continued practice of using Treasury payments and other remedies authorized by § 205.1991 after Subpart V was promulgated. *See, e.g.*, A's Auto Safety Service, 6 DOE (CCH) ¶ 83,014 (1981), *modified*, Office of Enforcement, 8 DOE (CCH) ¶ 82,594 (1981), *aff'd sub nom.* James Murphy, 20 FERC ¶ 61,331 (CCH) (1982); Sun Company, Inc. Consent Order, 45 FR 80947 (December 4, 1980). Moreover, by delegating to OHA the authority to establish Subpart V, 44 FR 8562, 8563 (Feb. 9, 1979), the Secretary of Energy did not indicate any intent to alter ERA's authority to enter into consent orders. The Comptroller General's interpretation of Subpart V is inconsistent with the division of functions within DOE, whereby ERA prosecutes enforcement actions and enters into consent orders with alleged violators, and OHA acts as the adjudicator *after* ERA files a proposed remedial order or petition. *See* 10 CFR Part 205, Subparts J, O and V. Subpart V did not modify this division of functions. ERA remained free to enter into consent orders incorporating remedies ERA deemed appropriate. Subpart V merely provided ERA with a new remedial option.

[3] Section 209 provides that: "Whenever it appears to any person authorized by the President to exercise authority under this title that any individual or organization has engaged . . . in any acts or practices constituting a violation of any order or regulation under [the EPAA], such person may request the Attorney General to bring an action in the appropriate district court of the United States. . . . In addition to [granting] injunctive relief, *the court may also order restitution of moneys received in violation of any such order or regulation.*" (Emphasis added).

[4] As a general matter, administrative agencies have wide discretion in the fashioning of remedies. *See, e.g., Mourning* v. *Family Publications Service, Inc.*, 411 U.S. 356, 376 (1973); *Atlantic Refining Co.* v. *FTC*, 381 U.S. 357 (1965), *reh. denied*, 382 *U.S.* 1000 (1966).

[5] Since TECA adopted the district court's opinion as its own, 601 F.2d 1191, citations are to the district court's opinion.

[6] The DOE's authority to fashion administrative remedies is supported by § 209(a)(1) of the ESA, 12 U.S.C. 1904 note, § 5(b)(5) of the Federal Energy Administration Act, 15 U.S.C. 764, § 4(b)(1)(f) of the EPAA, 15 U.S.C. 753, and § 301 and § 503 of the Department of Energy Organization Act, 42 U.S.C. 7151, 7193.

[7] In *Sauder*, TECA allowed DOE to collect the full overcharges associated with several leases from the operator, rather than requiring the agency to bring enforcement actions against each of the interest owners.

[8] In *Citronelle*, TECA also held that restitution is the Government's remedy to enforce public rights, not the private rights of purchasers (who may seek damages in private actions brought under section 210 of the ESA):

Actions by the United States under ESA § 209 are taken to enforce public, not private, rights. Thus, compensation is "a by-product of the agency's effort to re-establish compliance with its regulatory scheme."

669 F.2d at 723 *quoting Bulzan* v. *Atlantic Richfield Co.*, 620 F.2d 278, 282 (TECA 1980).

Company v. *DOE*, 569 F. Supp. 1204 (D. Del. 1983), *appealed on other grounds*, No. 3-37 (TECA Oct. 19, 1983); *United States* v. *Exxon Corp.*, 516 F. Supp 816 (D.D.C. 1983), *appeal docketed*, No. DC-91 (TECA June 22, 1983); *Pennzoil Company* v. *DOE*, 4 Energy Mgmt. (CCH) ¶ 26,415 (D. Del.), *aff'd on other grounds sub nom. Cities Service Company* v. *DOE*, 715 F.2d 572 (TECA 1983). For example, in *United States* v. *Exxon Corp., supra*, overcharges resulted from crude oil miscertifications that occurred after the commencement of the Entitlements Program in November 1974. These overcharges had been automatically dispersed among all refiners through their participation in the Crude Oil Entitlements Program, 10 CFR 211.67. 561 F. Supp. at 852–53.[9] The court held that the "broad scattering" of the effects of the violations "renders impossible the tracing of the overcharges to their ultimate victims and the calculation of the precise damages suffered by each." *Id.* at 853. *See* 10 CFR 212.83(c)(2)(iii); 10 CFR 212.93(c)(2); 10 CFR 212.183.

In these circumstances, the court found that restitution to the U.S. Treasury, the indirect restitutionary remedy sought by the DOE, was lawful. However, exercising its own equitable discretion under the ESA and EPAA, the court ordered another form of indirect restitution—payment of the overcharge funds to state governments for energy-related purposes as a means of benefiting the consumers who ultimately had borne the harm of Exxon's overcharges. In another case, restitution of crude oil overcharges to the U.S. Treasury was upheld as a reasonable remedy where DOE, in a remedial order, had found that the impact of the overcharge was untraceable. *Getty Oil Co.* v. *DOE, supra.*[10]

Restitution to miscellaneous receipts of the U.S. Treasury has also been upheld where the remedy was part of a DOE settlement agreement. *Pennzoil Company* v. *DOE, supra.* Indeed, in *Pennzoil Company*, the court held that "[t]he sole issue presented is whether the settlement is beyond the agency's authority or otherwise illegal." 4 Energy Mgmt. (CCH) ¶ 26,514 at 29,048, and the Treasury payment remedy was approved because the court concluded that the remedy is "within the authority of the DOE." *Id.*

DOE's remedial discretion is—as it must be—extremely broad in the consent order context because of the very nature of such settlements:

> Consent orders are the product of negotiation and compromise in which each party gives up something they might have won in litigation. [A Consent order] makes no attempt to define exactly legal rights and obligations.

Consumer Energy Council v. *Duncan*, 4 Energy Mgmt. ¶ 26,314 at 26,417 (D.D.C. 1981). DOE settlements, which resolve only matters between DOE and the firm, neither adjudicate a firm's liability nor the impact of alleged violations on purchasers of the firm's products. Moreover, they do not necessarily resolve only discrete issues where the alleged victims can be readily identified. Indeed, many consent orders cover nearly the entire range of an oil company's transactions, involving millions of customers most of whom cannot be readily identified or the amount of their injuries reasonably ascertained. Many of these settlements explicity state that it is infeasible to identify who was likely to have been injured and in what amount. Further, it is impracticable to provide individual refunds of a few dollars or cents to millions of affected consumers even if tracing and identification theoretically were feasible. In light of these circumstances, it is logical that when DOE exercises its prosecutorial discretion to settle a case instead of litigating it to its conclusion, the agency's remedial discretion is at its apogee. *See, e.g., Pennzoil Company* v. *DOE, supra; U.S. Oil Company* v. *DOE*, 510 F. Supp. 910, 914–15 (E.D. Wis. 1981); *see also Minnesota* v. *Standard Oil Company (Indiana)*, 516 F. Supp. 682, 662 (D. Minn. 1981). The Comptroller General's opinions, which would require the remedies for every settlement to be adjudicated, are wholly at odds with DOE's broad discretion to settle cases.

As the foregoing discussion shows, DOE's statutes, as judicially construed, permit the agency and the courts to utilize forms of indirect restitution without resort to Subpart V where direct restitution is infeasible. Arguments similar to those made by the Comptroller General have been repeatedly rejected by the courts. *See, e.g., Getty Oil Company* v. *DOE, supra, Pennzoil Company* v. *DOE, supra; United States* v. *Exxon Corp., supra. See also Kirkpatrick Oil and Gas Co.* v. *DOE*, 4 Energy Mgmt. (CCH) ¶ 26,400, 26,966 (W.D. Okla. 1982).

The courts have also upheld forms of indirect restitution other than deposits to the U.S. Treasury. *See United States* v. *Exxon Corp., supra.* Payments to the states and furnishing oil to the Strategic Petroleum Reserve ("SPR") can be proper indirect restitutionary remedies since they provide indirect benefits to the consuming public as would a payment to the general funds of the United States Treasury.

Payments to the Treasury benefit all purchasers by mitigating the need for additional taxes or reductions in government services. Similarly, an "in-kind" payment of crude oil for deposit into the SPR benefits all American consumers by providing a secure source of oil to alleviate any future oil shortages and their resulting price increases.[11] Payments to state governments whose citizens have borne the harm of alleged violations benefit the consumers within these states.[12]

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[9] The cost-spreading effect of the Entitlements Program is also described in Union Oil Co. v. DOE, 688 F.2d 797, 802 (TECA 1982), *cert. denied*, 103 S. Ct. 1188 (1983) and Cities Service Co. v. FEA, 529 F.2d 1016 (TECA 1975), *cert. denied*, 426 U.S. 947 (1976).

[10] In certain pre-enforcement actions brought against DOE, DOE has sought, and the courts have approved, referral of the issue of disposition of overcharge funds to the agency for determination in the first instance. In re Department of Energy Stripper Well Regulation Litigation, 578 F. Supp. 586 (D. Kan. 1983); Prosper Energy Corp. v. DOE, 4 Energy Mgmt. (CCH) ¶ 26,438 (N.D. Tex. 1983). In granting DOE's motion in the *Stripper Well Litigation*, the court specifically acknowledged that where it is impossible to determine who was injured "the equitable goals of restitution would mandate distribution to either the state governments or the federal government" for energy-related purposes or "a direct refund to the United States [T]reasury." 578 F. Supp. at 594–95.

[11] We note that these remedies are lawful where alleged crude oil overcharges were dispersed throughout the American economy. The Comptroller General's criticism of consent orders containing SPR remedies (62 Comp. Gen. at 390) is apparently based on a misunderstanding of the nature of the alleged violations which were settled and the effect of DOE's Entitlements Program and pass-through regulations in dispersing the alleged overcharges. In this regard, the Comptroller General believed that in Amoco Brand Committee, 10 DOE ¶ 82,566 (1983), the Office of Hearings and Appeals had directed refunds to purchasers claiming injuries attributable to alleged crude oil violations. *See* 62 Comp. Gen. at 390–91. This is simply incorrect.

[12] In section 155 of Pub. L. No. 97-377, 96 Stat. 1830 (1982), commonly referred to as the Warner Amendment to the Further Continuing Appropriations Act, 1983, Congress mandated a one-time distribution of up to $200 million of petroleum violation funds in DOE escrow accounts to states for energy-related purposes. DOE's remedial authority under the ESA and EPAA is not even referred to in the Warner Amendment and is thus unaffected by it. The Comptroller General, however, relying on a statement by Congressman Dingell that the Amendment "is a one-time provision" (128 Cong. Rec. H. 10635 (daily ed. Dec. 20, 1982)), has stated that the passage of the Amendment reflects Congress' view that direct distribution to the states is unauthorized under the ESA and EPAA. 62 Comp. Gen. at 394. The Comptroller General is mistaken since the Warner Amendment is neutral on this point and statements by a Congressman concerning the meaning of previous statutory enactments (here, the ESA and EPAA) years after their passage can be given little, if any, weight. *E.g.*, Quern v. Mandley, 436 U.S. 725, 736 n.10 (1978). In any event, the legislative history

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Where the effects of alleged violations are less than nationwide, payment to the affected states permits a more focused remedial action corresponding to the region that experienced the economic effects of the violations.[12]

The Comptroller General apparently considers that any payment which are made to states must be legally restricted to energy-related purposes under plans approved by DOE. 62 Comp. Gen. at 388. This interpretation is unsupported by any statutory or regulatory provision. As a means of indirect restitution, unrestricted payments to states can benefit state consumers, just as unrestricted payments to the U.S. Treasury will benefit consumers nationwide. While consumers may benefit where funds are to be used for energy assistance and conservation programs, such restrictions are not required. The harm was monetary; the benefit can be monetary.

IV. The Weight To Be Accorded the Comptroller General's Opinions

An agency's interpretation of its own regulations and enabling statutes is entitled to great deference from the courts. *E.g., Udall* v. *Tallman*, 380 U.S. 1, 16–17 (1965); *Pasco, Inc.* v. *FEA*, 525 F.2d 1391, 1400 (TECA 1975). In contrast, no such deference is owed to the Comptroller General's opinions concerning another agency's statutes and regulations in which the Comptroller General has no special expertise. *See, e.g., Green County Planning Board* v. *FPC*, 559 F.2d 1227, 1238–40 (2d Cir. 1977) (en banc); *Inner City Broadcasting Corp.* v. *Cardenas*, 584 F. Supp. 42, 49–50 (D.D.C. 1983). *See also NLRB* v. *Bildisco and Bildisco*, 104 U.S.L.W. 1188, 1198 n. 9 (Feb. 22, 1984). As one court has held in refusing to give weight to a Comptroller General opinion:

> [N]one of the factors weighing in favor of deference is presented. The GAO [General Accounting Office] possesses no technical expertise with respect to SBA [Small Business Administration] operations, the Comptroller General's decision came long after the passage of the 1972 amendment to the Small Business Act of 1958 at issue, and it reversed prior SBA practice while citing nothing in the legislative history to support its conclusions.
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> * * * * *
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> In interpreting this statute, this court * * * shall do so unfettered by the prior construction of the Comptroller General.

Inner City Broadcasting Corp. v. *Cardenas*, *supra*, 584 F. Supp. at 49–50 (footnote omitted).[14] Here, the DOE's remedial authority in resolving alleged oil pricing violations is predicated solely on those statutes (such as the ESA and EPAA) which the Department has been charged with administering, as well as regulations promulgated by the agency (and its predecessors) pursuant to those statutes. Moreover, the DOE, not the Comptroller General, has the responsibility and corresponding expertise for administering the energy regulatory programs; and the Comptroller General's views conflict with the meaning of the statutes and regulations at issue, as well as the relevant judicial decisions and longstanding agency interpretations and practices. In this context, we conclude that the Comptroller General's opinions addressed here concerning the meaning and effect of the statutory regulatory provisions governing the Department's remedial authority are not entitled to any deference and are incorrect on their merits.

V. Conclusion

The scope of DOE's restitutionary authority is measured by the broad purposes of the ESA and EPAA. Pursuant to these statutes, DOE must generally attempt to identify and provide refunds to injured purchasers (*i.e.*, provide direct restitution) where it is feasible. Notwithstanding the Comptroller General's opinions, DOE may also employ various forms of indirect restitution, including refunds to the U.S. Treasury and payments to state governments, where DOE enforcement officials determine it is infeasible to trace the impact of violations to particular purchasers. DOE's current practice of reliance on Subpart V proceedings to inquire into the impact of violations is not required by the regulations or the statutes DOE administers, but is within DOE's discretion under the regulations promulgated by this Department.

Theodore J. Garrish,

General Counsel.

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at least equally supports the view that distribution to the states is a permissible form of restitution. As was stated in the Senate debate:

> The conferees did not specifically address the disbursement of other funds collected as a result of overcharges. The proposal for distributing overcharge funds adopted by the Senate reflects the approach the *DOE should be following under existing law*, and in fact DOE has in part been proceeding in this fashion. It is the most appropriate method of providing restitution for the injuries suffered by the consumer. I hope that the action taken by the Senate and the conferees will provide a clear indication that the Department should proceed expeditiously to ensure the appropriate disposition of all the overcharges previously or hereafter collected.

128 Cong. Rec. S 15701 (daily ed. Dec. 20, 1982) (remarks of Sen. Kennedy) (emphasis added). At most, the legislative history of the Warner amendment indicates that members of each House expressed an opposing post-enactment interpretation of the Department's ESA and EPAA remedial authority, giving added weight to the Supreme Court's admonitions that such post-enactment views are unreliable indicators of the meaning of statutes. *See, e.g.*, Southeastern Community College v. Davis, 442 U.S. 397, 411–12 n.11 (1979); Quern v. Mandley, *supra*.

[13] Accordingly, we do not understand the Comptroller General's legal basis for his view that all funds which cannot be distributed to individually harmed purchasers must generally be refunded to the U.S. Treasury. *See* 62 Comp. Gen. at 391–92. In an earlier opinion, the Comptroller General had said that funds not distributed to injured purchasers are "moneys received for the use of the United States" and thus must be covered into the U.S. Treasury as miscellaneous receipts under 31 U.S.C. 484, *recodified and amended as* 31 U.S.C. 3302 (1982). 60 Comp. Gen. 15, 26–27 (1980). This assertion appears to have been abandoned and, in any event, is incorrect since DOE restitutionary funds are received for the benefit of injured purchasers; these monies are not the funds of the U.S. Government *qua* Government. Indeed, the Department of the Treasury has concluded that it "entertain[s] no doubt that [the funds collected by DOE] are not subject to the deposit requirement of 31 U.S.C. 484." *Enforcement of Major Refiner Cases: Getty Oil and Other Settlements: Hearing Before the Subcommittee on Energy and Power, Committee on Interstate and Foreign Commerce, House of Representatives*, 96th Cong., 2d Sess. 748, 748–49 (1980) (letter from Gene Godley, Assistant Secretary of the Treasury, to Congressman John D. Dingell). Courts have reached the same conclusion in similar contexts. *See, e.g.*, Emery v. United States, 186 F.2d 900, 902 (9th Cir.), *cert. denied*, 341 U.S. 925 (1951); Varney v. Warehime, 147 F.2d 238, 245 (6th Cir.), *cert. denied*, 325 U.S. 882 (1945).

[14] In *Greene County Planning Board*, relied on by the *Inner City* court, the Court of Appeals for the Second Circuit affirmed *en banc* a Federal Power Commission interpretation of the Federal Power Act where the Comptroller General had issued an opposing opinion. The Court held that the FPC's "interpretation of the Federal Power Act by the agency charged with its administration is entitled to great deference from this Court." 559 F.2d at 1239 n.2, and that judicial decisions interpreting statutes and regulations are controlling vis-a-vis Comptroller General opinions. *Id.* at 1238–39; *see also Alexander* v. *FERC*, 609 F.2d 545, 549 (D.C. Cir. 1979). Moreover, as the *Inner City* court subsequently noted, "the majority in *Greene County Planning Board* declined to give the Comptroller General's opinion even the modicum of deference courts give an enforcing agency's statutory interpretations, as three dissenting judges urged it to do." 584 F. Supp. at 50 n. 8. Indeed, the Comptroller General himself has stated that he is bound by an agency's interpretation of its own statutes and regulations as long as it is reasonable:

> [W]here the agency interpretation is merely one of several reasonable alternatives, it must stand even though it may not appear [to the Comptroller General] as reasonable as some other.

53 Comp. Gen. 143, 145 (1973); *see also* 61 Comp. Gen. 683, 687 (1982); 57 Comp. Gen. 347, 350 (1978).

QUESTIONS FROM SENATOR CARL LEVIN

DOE'S BUDGET IN FY' 85 CONSERVATION AND RENEWABLE ENERGY

Question 20. The Comptroller General concluded that the funds deposited as miscellaneous receipts without prior efforts at restitution are subject to retrieval by DOE, with distribution to follow the appropriate administrative proceedings.

- When does DOE intend to retrieve and distribute these funds?

Answer: As stated in response to question 19, DOE has concluded that it has not paid any funds into the Treasury erroneously. Accordingly, no retrieval or alternative distribution is necessary or appropriate.

QUESTIONS FROM SENATOR METZENBAUM

APPLIANCE EFFICIENCY STANDARDS

Question 21: When the Congress enacted in 1978 the statute calling for appliance efficiency standards there was a quid pro quo involved. The appliance manufacturers consented to meet uniform Federal standards in return for Federal preemption of state regulation in this area. Now this administration has taken us full circle haven't you. Through use of the "no standards standard" you have in effect refused to issue Federal standards and through your liberal waiver policy consented to allow over 20 states to regulate the appliance industry. For the appliance industry when President Reagan was elected, the good news was that he disfavored Federal regulation. The bad news was that he favored states' rights. Where are we now on appliance efficiency standards?

Answer: The Department has issued final rules with respect to eight types of appliances (clothes dryers, kitchen ranges and ovens, refrigerators and refrigerator-freezers, freezers, water heaters, room air conditioners, furnaces and central air conditioners), in which the Department determined that an energy efficiency standard for any of these products is not justified. DOE determined that for each of these products, except central air conditioners, an energy efficiency standard would not result in a significant conservation of energy and would not be economically justified. With respect to central air conditioners, DOE determined that an energy efficiency standard would result in a significant conservation of energy, but would not be economically justified.

As shown in the attached table, 26 states have filed petitions for an exemption from Federal preemption of their energy efficiency standards and the appliances for which they were filed. On March 27, 1984, DOE published a final rule in the Federal Register which grants the petitions submitted by the States of California, New York, Wisconsin, Minnesota, and Oregon requesting that their standards requiring intermittent ignition devices for clothes dryers and/or kitchen ranges and ovens be exempted from Federal preemption. By the end of July 1984, we expect to publish proposed rulemakings addressing the petitons received from 26 States for one or more of the following appliances: refrigerators and refrigerator-freezers, freezers, water heaters, room air conditioners, central air conditioners, and furnaces. One of these petitions, from Rhode Island, seeks an exemption of standards for kitchen ranges and ovens, but was filed too late for inclusion in the March 27, 1984, rulemaking.

In 1985, we expect to publish proposed appliance efficiency standards rulemakings for the remaining categories of appliances. The remaining appliances are: television sets, dishwashers, clothes washers, humidifiers and dehumidifiers, home heating equipment not including furnaces, heat pump water heaters, and heat pumps (a category of central air conditioners). Once DOE issues final rules on these appliances, the Department will have issued appliance standards for each of the 13 appliances identified in the legislation.

STATE PETITIONS

STATE	CLOTHES DRYER	REFRIG. REFRIG-FZR.	FREEZER	WATER HEATER	ROOM AIR CONDITIONER	CENTRAL AIR CONDITIONER	FURNACE	RANGES & OVENS
Arkansas				x	x	x	x	
Virginia				x	x	x	x	
Florida				x	x	x	x	
Pennsylvania				x	x	x	x	
Wisconsin	x*				x	x	x	x*
South Carolina				x		x	x	
New Mexico				x	x	x	x	
Georgia				x		x	x	
Rhode Island				x	x	x	x	x
New Hampshire				x	x	x	x	
Massachusetts				x	x	x	x	
California		x	x	x	x	x	x	x*
Oregon	x*			x	x	x	x	x*
New York		x	x	x	x	x	x	x*
Missouri				x	x	x	x	
Texas				x	x	x	x	
New Jersey				x	x	x	x	
Illinois		x	x	x	x	x	x	
Utah				x	x	x	x	
Iowa				x	x	x	x	
West Virginia				x	x	x	x	x*
Minnesota	x*			x	x	x	x	
Washington				x	x	x	x	
Kansas						x		
Hawaii				x	x	x	x	
Tennessee				x	x	x	x	

* Separate petition filed for these products.

QUESTIONS FROM SENATOR METZENBAUM
Appliance Efficiency Standards

Question 22: Do you see any rational basis for the mess we are in now of appliance manufactures flying around the country trying to keep 20 states from regulating them while the sum total of the Federal government's effort is to allow the states to jump back in and regulate but only after imposing considerable red tape in their path?

Answer: Since before enactment of the Federal appliance standards legislation, all 50 states, or localities within the States, have operated many differing appliance efficiency standards with little apparent adverse effect on the appliance industry. Since DOE's issuance of final rules, the appliance standards in effect in those States that have not petitioned DOE for an exemption from preemption of their energy efficiency standards are preempted. For those States that have filed petitions, their standards will remain in effect unless DOE issues a rule denying their petition.

The impediments to DOE's processing State waivers on appliance standards are based upon the requirements of Section 327 of the Energy Policy and Conservation Act (EPCA), Pub. L. 94-163, as amended by the National Energy Conservation Act (NEPCA), Pub. L. 95-619. Like the statute, DOE regulations, based upon the minimum requirements of Section 327 of the Act, do not allow for the granting of a State petition until a rulemaking has been conducted. Expeditious determination on State petitions are hampered by this requirement.

QUESTIONS FROM SENATOR DOMENICI

ELECTRIC VEHICLE PROGRAM

Question 23: Is the amount of funding for Electric Vechile battery development adequate?

Answer: The FY 1985 funding request for battery development is considered adequate for the Government's role in technology development.

Question 24: What are the total funds for EV battery development by type of battery technology?

Answer: The FY 1985 budget request under the Interior Appropriations Bill includes $800,000 for development activity on the sodium-sulfur battery technology.

The FY 1985 budget request under the Energy and Water Developments Appropriations Bill includes $2,000,000 for sodium-sulfur research; $100,000 for zinc-bromine research; $2,000,000 for aluminum-air research; and $1,800,000 for fuel cell research that are applicable to electric vehicle technology needs.

QUESTIONS FROM SENATOR DOMENICI

ELECTRIC VEHICLE PROGRAM

Question 25: What near-term battery technologies have rearched the final stages of development? Is there industry agreement on this?

Answer: As far as the government role is concerned, the near-term battery technology development efforts will be completed with FY 1984 resources. The near-term lead-acid and nickel-iron battery technologies have reached the final stages of development for government support. There is general industry agreement on this assessment.

Question 26: When do you expect the near-term electric van development to be completed?

Answer: The dual shaft propulsion technology development suitable for van application has recently been contracted with the Eaton Corp. The work is scheduled to be completed in the summer of 1988.

Question 27: Are there any plans for the Site Operator User Task Force to field-test the near-term electric van?

Answer: Although interface and discussions have been established with the Site Operator User Task Force it is premature to make definitive plans about field testing the electric vehicle technologies under development for van application.

QUESTIONS FROM SENATOR DOMENICI

ELECTRIC VEHICLE PROGRAM

Question 28: How will the auditing of $10.077 million from "previous year balance" toward the 1985 budget request in energy conservation affect the electric vehicle program? How much of the $10.077 was credited from the electric vehicle program? Wouldn't this money be more appropriately used in the 1984 research activities, via carryover of the funds.

Answer: The Office of Management and Budget released all research and development amounts that were deferred under energy conservation. This amount totalled $8.577 million from the previous year balance and will be used for program purposes. This carryover funding is being used in FY 1984 research activities that include the electric vehicle program.

QUESTIONS FROM SENATOR WARNER

COAL-FIRED LOCOMOTIVE

Question 29: I am very interested in your FY 1985 budget request for the transportation program - specifically your Vehicle Propulsion subprogram and your Alternative Fuels Utilization subprogram.

I applaud your efforts to improve energy efficiency in transportation and to develop new technologies which can serve as alternatives to those based exclusively on petroleum.

I have been working to develop a coal-fired locomotive which when implemented would reduce this country's use of oil by four billion gallons yearly. Finding the funding for a prototype coal-fired locomotive has not been easy.

Within your Vehicle Propulsion subprogram is there the capability to fund the development of a prototype or prototypes of a coal-fired diesel locomotive?

Answer: The Vehicle Propulsion subprogram has focussed on the highway transportation sector since it is the largest consumer of petroleum. The FY 1985 budget request does not include funds for development activities in the non-highway sector, which would include locomotives. However, a large portion of the research and development efforts in the Heavy Duty Transportation project are directed towards the uncooled or adiabatic diesel engine, and this technology is indirectly applicable to a coal-fired locomotive. In addition, research in utilization of coal as a fuel for heat engines such as gas turbines and diesels is an element of the DOE Fossil Energy Program, and continuous coordination is maintained between related program offices within DOE.

QUESTIONS FROM SENATOR WARNER
Coal-Derived Fuel

Question 30: Your Alternative Fuels Utilization subprogram is designed to encourage the use of non-petroleum based fuels in transportation. These fuels would be derived from many sources including oil shale and coal. As coal is the nation's most abundant resource I am specifically interested in the efforts this subprogram is undertaking to utilize coal.

Answer: Coal and oil shale have been recognized for a decade as the only indigenous non-petroleum resources sufficient to singularly provide fuel for highway vehicles. Both methanol and liquid fuels from synthetic crudes have been investigated as to potential utilization. It has only recently become possible to make test-sized quantities of coal-based synthetic fuels. These fuels will be used in planned FY 1985 activities to provide a technical data and information base for industry vehicle designers. Over the past several years liquid fractions of products from Solvent Refined Coal, Exxon Donor Solvent and other experimental projects have been used in a similar fashion and thereby provide additional related technical data. (Counterpart activity on products from oil shale crudes is also in progress). Previous utilization activities have shown that test results provide valuable inputs to process plant designs that can result in large investment savings.

QUESTIONS FROM SENATOR WARNER

METHANOL FROM COAL

Question 31: Have you looked at or will look at the possibility of methanol derived from coal as a source of fuel for our transportation systems?

Answer: Methanol-from-coal was identified in 1974 as a high priority option for extending and/or replacing gasoline. As a result, major effort of DOE's Alternative Fuels Utilization Program (AFUP) over the last decade was in this and related areas. The resulting data and information base has provided the fundamentals on which industry has built its capabilities, now evidenced in commercial alcohol/gasoline blends and sizeable neat-alcohol experimental vehicle fleets. The AFUP has also provided technical support for several years to the Department of Transportation, Urban Mass Transportation Administration methanol bus projects. Once methanol is established in the fuels market, it is expected that serious industrial consideration will be given to plants using coal feedstock since its economics are apparently close to being competitive with gasoline.

QUESTIONS FROM SENATOR MATSUNAGA

CONSERVATION

Question 32: Mr. Secretary, your FY 1985 budget submission zeroes out funding for State Energy Conservation Programs (SECP), the only source of Federal aid to the States for financing state energy agencies. The enabling legislation, the Energy Policy and Conservation Act of 1975, had certain macro-targets for energy savings in each State by 1980 as well as certain specific national norms for thermal and lighting standards in building codes and the like. Can you give us some idea on the degree of success, or lack of it, that this legislation achieved, especially in fostering specific proscriptive standards for energy efficiency at the state and local level? Also has your office done any sort of a survey to determine whether all 50 States will be able to retain an adequate level of state competence in energy conservation in the absence of the SECP support? We do have other Federal legislation on the books which pre-supposes this capacity on the part of the States, the Energy Emergency Preparedness Act for one, the Schools-Hospitals program for another, but there is no other Federal support for this type of activity except for an after-the-fact reimbursement device for Schools-Hospitals administration which has not been considered all that satisfactory from the States' standpoint in the past. Can you speak to these concerns?

Answer: Analysis of the energy savings reported by the States in 1980 under the State Energy Conservation Program (SECP) showed that the States were able to save 60% of the overall energy savings goal for 1980. The shortfall in the State 1980 energy savings goals was due to implementation difficulties of the required program measures. The primary problem was that the original estimates of the time required for effective implementation of some required program measures were overly optimistic. For example, in attempting to implement mandatory thermal and lighting efficiency standards for new buildings, account was not taken of the wide variations among States and their political subdivisions in the capabilities and resources required to adopt and implement these standards.

The mandated activities required in the legislation have been adopted by all of the States, including to the extent practical, based on State and local laws, adoption of lighting and thermal efficiency standards for buildings. The Annual Report to the President and Congress on the SECP for calendar year 1981 reported a cumulative savings of 3.18 Quads and the 1982 Report showed cumulative savings of 3.72 Quads. The 1983 Report which is being compiled and is scheduled for publication in July will show a cumulative savings of 3.89 Quads.

We have not done a recent survey to determine whether the States will be able to retain staff in the absence of SECP support. We believe, however, that State Programs have matured and that their benefits are better understood at the State level. Therefore, the Department believes that this program should become a State responsibility and that the States are in the best position to judge their effectiveness and continue them if they so desire. Some States do use the staff of energy offices to assist in administering other Federal energy programs. We believe this is all the more reason that States should be willing to devote State resourecs to maintaining the staff of the energy offices.

QUESTION FROM SENATOR MATSUNAGA

CONSERVATION

Question 33: Mr. Secretary, in your appearance before the Energy Subcommittee of the Appropriations Committee last March, you stressed that your budget proposal emphasizes application of the previous public investment in energy conservation R&D, or "Technology Transfer,"if you will. In this light, I find it puzzling that your budget proposes no funding at all for the Energy Extension Service, the technology transfer arm for both conservation and renewable energy applications of your department. Can you explain this?

Answer: The Department's Technology Transfer initiative is a high priority. We are reviewing methods of information transfer and developing options to increase the capability of the market to support development and availability of credible, accurate information on costs and benefits of energy efficient technologies and techniques.

The role of the Department's conservation and renewable programs will be to make available the information resulting from Federal R&D efforts to appropriate technology transfer agents or mechanisms which include state and local governments. The FY 85 budget does not contain funding for the EES because we believe it is a State responsibility to fund and operate such service. The Department prefers to devote funds transferred to the States to programs which directly conserve energy through the installation of energy conservation equipment and supplies, thus enabling those recipients to improve their energy efficiency.

QUESTIONS FROM SENATOR MATSUNAGA

CONSERVATION

Question 34: At the time the States were considering participation in the EES program, following the pilot state initial undertakings in the late 1970's, one of the selling points as far as state governors were concerned was that the program offered a way to build a field staff competent to play the emergency assistance role proposed for the States in the Energy Emergency Preparedness Act 1979. Since the kind of energy emergency contemplated in that legislation is very much concern once again and there is no Administration initiative for assisting the States in this role in a financial way, do you think it wise to dismantle this field staff, or put it in jeopardy by withdrawing Federal aid at time?

Answer: We believe that any decision to dismantle staff should be left to the State and that the Federal funds to the States can be used most effectively in the grant programs.

QUESTIONS FROM SENATOR MATSUNAGA

Solar Thermal

Question 35: With respect to the Small Community Solar Experiment Project, it is my understanding that a serious potential problem has arisen concerning the availability of an advanced engine module design for solar application by United Stirling, a Swedish company. It appears that an exclusive agreement between United Stirling and McDonald Douglas, an American firm, may not allow the marketing of the United Stirling engine, which is, at the present time, the only viable engine available for use with the parabolic dish electrical generating system developed for the Small Community Solar Experiment Project. It is generally agreed that the non-availability of this crucial engine module may severely restrict the success of the Small Community Solar Experiment Project and other related renewable energy projects which might incorporate the extraordinarily efficient United Stirling engine into their designs. In light of the fact that the Secretary of Energy has authority under 41 CFR Part 9-9 to require that nonexclusive licenses be granted to responsible parties requesting access to technology developed with federal research dollars, I would appreciate your providing the Committee with your view of this situation and whether the Department of Energy is taking, or plans to take, any action under its existing authority to ensure the availability of key components for the parabolic dish module to be used in the Small Community Solar Experiment Project.

Answer: The solicitation for two Small Community Solar Experiments; at Osage, Kansas and Molokai, Hawaii, was released in December 1983. Proposals have been received and reviewed, but the Source Evaluation Board has not completed its deliberations and no decisions have been reached regarding either site. It should be noted that the solicitation was non-specific as to engine type, although it would be desirable to have two different engine technologies represented, one at each site. In the event that no acceptable proposals were received for either or both sites, DOE would be unable to make a contract award for the affected site or sites. At that point, DOE would examine the options available to it and decide on an appropriate course of action.

QUESTIONS FROM SENATOR MATSUNAGA

Ocean Energy

Question 36: The Department's decision to request funding for OTEC in the Fiscal Year 1985 budget submission was well received by the Congress. It is hoped that this action represents a recognition of the Congress' determination to keep this promising renewable energy program moving forward and a new commitment on the part of the Department of Energy to help commercialize the technology. Would you explain to the Committee what the Department's long-term plans are for OTEC research and development? I am particularly interested in knowing whether or not a multi-year plan for OTEC research is being contemplated and in what direction (what specific areas of OTEC or problems with the technology) the future research is expected to move.

Answer: A multiyear plan for OTEC research is being prepared. Since the plan is in its early formulation stage, a definitive discussion of the research areas it will address is premature. Within the context of this plan, DOE will evaluate the need (if any) of research responding to issues impacting OTEC life cycle costs and technical risk in areas such as:

- OTEC power systems for simultaneous production of electricity and fresh water (open cycle evaporators with lower cost ceramic or thermoplastic closed cycle condensers)
- Alternative methods of reaching the deep ocean cold sink
- Open cycle turbines and direct contact processes, and
- The use of the latent heat of evaporation of warm seawater in the power system process.

QUESTIONS FROM SENATOR MATSUNAGA

Ocean Energy

Question 37: I am concerned that the $0.6 million requested by the Department for modifications of the Seacoast Test Facility (STF) at Keahole Point, Hawaii, is not adequate funding to complete the upgrading of the facility to permit it to carry out planned OTEC research and experimental testing programs. It is my understanding that a minimum of $1.7 million will be needed for design, fabrication, and assembly of the new components required for the STF which include upgraded seawater handling systems and measurement and control instrumentation. I would appreciate your explaining to the Committee how the requested $0.6 million would be spent for STF modiciations and identifying areas which would not be addressed by this level of funding. I would also appreciate your outlining how the Department anticipates the STF to be utilized for OTEC research in both the near-term and in future years of this program.

Answer: Within the context of an Ocean Energy multiyear plan which is currently under development by DOE, the potential need for research in a number of areas relating to OTEC will be evaluated. Based on the results of this evaluation, the future role (if any) for Federal participation at the Seacoast Test Facility can be specifically assessed. Accordingly, conjecture as to a specific program of experiments is premature at this point in time.

QUESTIONS FROM SENATOR MATSUNAGA
Hydrogen Research

Question 38: It is my understanding that the Department has a Hydrogen Energy Coordinating Committee which is designed to improve communications between various groups performing research relating to hydrogen production processes and storage methods. Please provide for the record an overview of the makeup of the Coordinating Committee and its functions. I would also appreciate your describing to what extent the Committee is involved in actual coordinating of hydrogen research programs, i.e., how frequently the Committee meets, what effect has it had on program planning and integration, and indicate when future meetings are contemplated.

Answer: The Department of Energy is continuing a multi-year research and development program studying the generation, storage, transmission and use of hydrogen. These projects are coordinated through the Hydrogen Energy Coordinating Committee (HECC) which was organized in the Energy Research and Development Administration (ERDA), and was continued when ERDA programs were incorporated into the Department of Energy. The committee is made up of representatives from offices within DOE which are presently doing work in hydrogen or have an interest in the subject. This committee functions to improve communication among various groups and insures that there is no duplication of effort regarding hydrogen research. The committee takes no part in the actual planning of hydrogen work other than supplying information on current and past hydrogen related research. The HECC holds semi-annual meetings at which recent progress is reviewed, plans are exchanged, and a formal talk on a current topic of interest to hydrogen researchers is presented. The next meeting is scheduled to occur after the 5th World Hydrogen Conference in July. Minutes of these meetings are prepared and distributed to attendees and other interested persons. In addition, the HECC publishes an annual summary of DOE hydrogen programs.

QUESTIONS FROM SENATOR MATSUNAGA

Photovoltaic-Hydrogen System

Question 39: The Congressional Research Service has brought to my attention the fact that after a seven year, $25 million research effort, Texas Instruments has ceased work on a rooftop residential solar hydrogen energy system--a system considered among the most promising of the emerging renewable energy technologies. It is my understanding that the company's decision not to go forward into pilot production had nothing to do with the technology, but rather its inability to raise enough funds to carry the project into commerical production. Would you explain what the Department of Energy's role was in the Texas Instruments solar hydrogen development project, whether the Department viewed the project as technically and economically feasible, and whether the Department believes that the future potential of the technology is high enough to warrant further development (perhaps with DOE financial assistance) designed to bring down commercialization costs?

Answer: In 1975, scientists of Texas Instruments (TI) conceived and filed a patent disclosure on a novel solar energy system. TI invested its own funds to initiate the applied research of this concept. In 1978, TI approached the Department of Energy (DOE) with a well-developed program to bring the project and technology to a stage where industry would normally assume complete responsibility for commercialization. In addition, TI was willing to cost-share. A four-year, $18 million cooperative agreement was negotiated between TI and DOE whereby TI agreed to cost-share 22.2 percent and DOE would contribute 77.8 percent. Also TI agreed that if the project was commercialized, TI would reimburse DOE out of future profits from the sales of the system, if realized. After adjustments in levels of effort over the four-year period, the total cost was $17,800,000 of which $12,500,000 was provided by DOE and $5,300,000 by Texas Instruments.

The applied research phase of the TI Solar Energy System was finished on September 30, 1982 with the completion of testing of a developmental module (TISES D) exhibiting approximately 7.7 percent system efficiency of which 2.4 percent was electrical. The associated durability goals were met. In order to meet TI's commercialization goals of 10-18 percent total efficiency and 8-10 percent electrical efficiency for a production module, extensive further development would be required. From the data presented at the final project review, these appear to constitute viable goals. However, TI decided that it would not proceed alone in any further development of this system, and it was unsuccessful in finding a venture partner during a search in 1982 and 1983. DOE has focussed available funding on photovoltaic areas of more promise.

Department of Energy
Washington, D.C. 20585

October 17, 1984

Honorable Pete V. Domenici
Chairman, Subcommittee on Energy
  Research and Development
Committee on Energy
  and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

On April 24, 1984, Under Secretary Collins appeared before your Subcommittee to discuss the FY 1985 authorization request for conservation and renewable energy research and development programs.

Following that hearing, you submitted a follow-up question for our response. Enclosed is the answer to that question which also has been provided directly to Senator McClure and the Committee staff.

If you have any questions, please call Ingrid Nelson or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

bcc: Mr. Al Astrin

Follow-up Question to April 24, 1984 Authorization Hearing

It is the Committee's understanding that the Southwestern states have voiced a strong interest in pursuing biomass energy projects within their region.

Question: Does the Department of Energy have any plans to implement a Regional Biomass Program for the South-West region, similar to those regional biomass energy programs that have been established in all other regions of the country?

Answer: The Department has established regional biomass energy programs for the Pacific Northwest, the Southeast, the Northeast and the Great Lakes regions to assist in the transfer of appropriate and established biomass energy technologies and to address the specific requirements of these regions. For FY 1985 these regional activities will continue at a level of support not less than that of FY 1984 in accordance with Congressional direction. While no additional regional programs are planned, the Department will continue to sponsor significant research efforts for the development of biomass energy technology appropriate to the arid environments of the southwestern United States. As technologies appropriate to those environments are developed, the Department will be engaged in efforts to transfer that knowledge.

APPENDIX IX

Additional Statement Submitted for the Record

Johnson Controls, Inc.

Hearing on FY 1985 Authorization for the
Department of Energy's Conservation and
Renewable Resources Program - ~~March 16, 1984~~
April 24, 1984

Testimony Submitted to:

Energy Research and Development Subcommittee
Energy and Natural Resources Committee
U.S. Senate

By:

Vincent M. Halsall
Vice President
Globe Battery Division
Johnson Controls, Inc.

We believe there are some facts that must be understood by the members of this Subcommittee in consideration of authorizing FY 1985 funds for the Department of Energy's Conservation and Renewable Resources Program. Our comments specifically address funding of aqueous mobile battery systems for electric vehicle applications.

As background, Johnson Controls through its Globe Battery Division, is the largest U.S. manufacturer of automotive batteries. We have been a subcontractor to the Department of Energy (DOE) for battery development since 1976 and have also served as a subcontractor to some electric vehicle development programs.

Development of an advanced lead-acid battery system for electric vehicles is not complete. While preliminary testing of our advanced cells by Argonne National Laboratory has shown positive results, a significant amount of investment is required to meet established energy density goals.

Our development of advanced lead-acid batteries for electric vehicles will come to a virtual halt if funding by the DOE is discontinued. We are strong advocates of a future electric vehicle market; we have made significant investments in battery development for this market -- over and above the more than $2 million committed by us under DOE contracts. But the near-term likelihood of a sizeable electric vehicle market is too remote for us - without Federal support - to expend the capital needed to bring an advanced lead-acid system to commercialization.

The advanced lead-acid battery deserves DOE funding. It is the only system currently powering existing electric vehicles and will be the system needed to furnish reliable power for commercial electric fleets. It is the foremost system for which significant progress - a 60% improvement in energy density in six years - has been demonstrated under DOE research programs. Its improving performance is a moving baseline against which unproven, high-risk "Advanced" systems must be measured. It is the only system for which additional performance gains (of 30% to 40%) can be confidently predicted.

The U.S. Government must support U.S. industry in efforts to establish a technology that will reduce our reliance on foreign energy sources. It has been internationally recognized that government/industry partnerships are critical. Japan, Canada, Germany and England, for example, have put such programs in place. Unless the DOE sets and supports a development timetable, U.S. industrial progress will seriously lag. While the 1970s are behind us, uncertainties of oil suppliers are not. Will the U.S. be better prepared for future international economic disruptions?

Funding should also be authorized for the gelled electrolyte battery systems. Recent DOE testing indicates that, if given the appropriate impetus, presently commercialized gelled electrolyte, lead-acid batteries would show good potential to meet the needs of electric vehicle applications where low-maintenance is a priority and limited range is acceptable, e.g. designated-route fleet vehicles. While we suspect that needed performance gains are achievable, we will not undertake applications without Federal support.

In summary, we believe that continued support by the DOE is imperative to further the accomplishments of the past several years. To drop support of aqueous mobile systems -- our best hope for a viable electric vehicle battery -- will mean that the multi-million dollar investments of U.S. taxpayers and industry will have been a fruitless exercise.

Thank you for giving these views your sincere consideration.

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